Chapter Comm 22

ENERGY CONSERVATION

Note: Chapter Ind 22 was renumbered to be chapter ILHR 22, Register, February, 1985, No. 350, eff. 3-1-85. Chapter ILHR 22 was repealed and recreated to be chapter Comm 22, Register, January, 1999, No. 517, eff. 2-1-99.

Subchapter I — Scope and Application

Comm 22.01 Scope.

This chapter applies to all one- and 2-family dwellings covered by this code.

Comm 22.02 Application.

(1) This chapter is not intended to conflict with any safety or health requirements. Where such conflict occurs, the safety and health requirements shall govern.

(2) This chapter allows the designer the option of using Subchapters V and VI or Subchapter VII to demonstrate compliance with equipment and thermal performance requirements. The designer shall identify on the plan submittal form what method or subchapter is being used, and indicate the design criteria and how it is being applied. Requirements of all other subchapters apply regardless of choice.

(3) (a) Additions to dwellings may follow the energy code that was in effect at the time the current dwelling was originally constructed, provided the footprint of the addition has an area equal to 50% or less of the area of the footprint of the current dwelling.

(b) Portions of garages, porches and decks without living space directly above them are excluded from consideration under sub. (a).

<u>Use of REScheck for Addition to Older Dwellings</u>

You may use REScheck to determne compliance with this section. We will conservatively accept designs that fail to meet the current code by 12%. Alternatively, you can submit detailed calculations for greater deviations to show compliance.

Note: The UDC Energy Worksheet specifies the insulation requirements to apply to the dwelling envelope. A copy of the worksheet is in the appendix. Other code requirements apply to material and equipment identification, sealing of the building envelope, the heating and cooling system including ducts, and the hot water system. Copies of worksheets may be obtained from the Department of Commerce, Safety and Buildings Division P.O. Box 2509 Madison, WI 53701.

<u>Introduction</u>

Wisconsin has a keen interest in conserving energy because we import about 95 percent of what we use. For our state's economic well-being, the legislature has enacted enabling legislation to set building code standards for energy conservation.

This chapter of the UDC sets minimum standards for energy conservation for new one- and two-family dwellings. It sets requirements for insulation and moisture protection of the building envelope and capacity and efficiency requirements for heating, ventilating and air conditioning systems.

The standards attempt to satisfy the human comfort needs of proper temperature, air movement and humidity as well as economical and building-preserving construction and operation. To assist you in better understanding these standards, we've included the following energy basics section. Following that is the code section-by-section commentary.

Note that the effective date of the original energy conservation standards was <u>December 1, 1978</u>, differing from the June 1, 1980, effective date of the other chapters of the UDC.

There are separate thermal envelope, moisture control and ventilation requirements for nonelectrically and electrically heated dwellings. In this commentary, information that applies to both sets of standards will appear only in the nonelectric standards sections.

Some Energy Basics

The following information is offered as background material to the intent and proper application of the Ch. Comm 22 requirements.

Chapter Comm 22 requirements can be put into the four categories of heat loss control, moisture control, ventilation design, and heating equipment requirements with some overlap between the four.

I. Heat Loss

The heat loss control requirements of Ch. Comm 22 are meant to limit heat transfer. Heat transfer is the tendency of heat or energy to move from a warmer space to a cooler space until both spaces are the same temperature. Obviously, the greater the difference in temperatures, the greater the heat flow. There are three types of heat transfer:

- *Radiation - transfer of heat through space. An example is your body heat radiating out a closed window on a winter night. The glass is cold so there is no radiation to you and it is a poor reflector of your own heat back to you. Another example is sunshine coming in through a window.*

- *Conduction - transfer of heat through a material. An example is your warm hand held against the inside surface of a cold exterior wall.*

- *Convection - transfer of heat by moving masses of air. An example is heated air leaking out through door and window openings.*

The code does not say much about radiative heat losses. It does say a lot about conductive and convective heat losses. Let's discuss these further.

A. Heat Loss By Conduction

1. C-values and k-Values

A measure of a material's ability to Conduct heat is its "C"-value which is expressed in BTUs per (hour)(oF). A BTU is a British Thermal Unit which is the heat required to raise one pound (about a pint) of water by one degree Fahrenheit and is roughly equal to the heat given off by the burning of one kitchen match. A human body gives off about 400 BTUs per hour. Since a C-value is a flow rate of heat, it needs a per time unit similar to other rate measures such as speed, "55 miles per hour." An hourly rate is also used in the C-value. Finally, as you *recall, heat flow is greater as the temperature difference increases. So the C-value needs to be expressed in terms of what the difference is. For simplicity, it is taken at 1 degree Fahrenheit difference.*

Another term to be familiar with is a <u>"k"-value</u> which is merely the C-value for one inch of material.

Typically, building components such as walls or ceilings consist of a "series" or layers of different materials as you follow the heat flow path out. However, you <u>cannot</u> add C-values together because if you were to take two insulating materials with a C-value of .5 each and were to add them together, you get the result of a total C-value of 1.0. This would mean that the heat flow rate has increased with the addition of <u>more</u> insulating material. Obviously then you <u>cannot</u> add C-values to find the "series" value.

2. *R-Values*

Therefore, we now have to bring in the perhaps more familiar "R"-value which is a measure of a material's Resistance to heat flow and is the inverse or reciprocal of the material's C-value (R=1/C).

So if a material has a C-value of .5, it has an R-value of 2 (1/.5). If you have to add two materials in series or layers, say each with a C-value of .5, you take the inverse of both to get an R-value for each of 2. These can be added together to get a total R-value of 4. Usually materials are labeled or tables are written so that the material's R-value is given, which relieves you of finding the inverse of the material's C-value.

3. *U-Values*

For thermal heat loss calculations, we normally use "U"-values (U for Unrestrained heat flow or transmittance) which is a material's C-value but also includes the insulating effect of the air films on either side of the material. So it is, therefore, a smaller number (less heat flow).

A U-value can also refer to thermal transmittance of a series of materials in layers. To obtain a U-value for such an assembly, you add the individual R-values of the layers and the air films on either side of the assembly. Then you take the reciprocal of the total R-value to get the total U-value of the assembly (U = 1/R). (As with C-values discussed above, you can not add U-values for series calculations.)

4. *Heat Loss Calculations*

The purpose of these C-, k-, R- and U-values is to be able to calculate heat loss through a building component (wall, ceiling, floor). The basic equation is U x A x TD = Heat Loss or

U x Area x Temperature Difference (dF)
= Conduction Heat Loss (BTU/HR)

So to find the heat loss per hour through a building section of wall, you:

- *determine its U-value by finding the inverse of the sum of individual R-values for each layer of material;*

- *decide on the inside and outside temperatures (in the case of the UDC, the winter design temperatures are mandated);*

- *measure the surface area of the building section;*

- *multiply these numbers together and get a result in BTUs per hour.*

If you did this for every different building section (solid wall, window, ceiling, etc.), you could obtain the total heat loss through the envelope at design temperatures, which is the worst case situation. Normally this maximum figure along with the heat loss by infiltration (see discussion later) is used to size the furnace or other heating source. It is referred to as the heating load.

If you wanted to know the total envelope loss for a heating season, you do a degree-day calculation. A degree-day is the difference between 65°F and the average temperature for a day if it was below 65°F. If this calculation is done for each day of the heating season, you can find the total heating degree-days for the year. This can be plugged into a modified version of the heat loss calculation as follows:

$$U \times \text{Surface Area} \times \text{Degree-days} \times \frac{24 \text{ hours}}{\text{Day}} = \text{Season Heat Loss}$$

5. U-Overall

One more term to know is U-overall or Uo which refers to the overall U-value of a building component such as a wall or ceiling. For example, a wall will have different individual U-values for the windows, stud cavities and stud locations. The UDC sets a minimum Uo for each overall component surface. If a designer has a large window area, more insulation will need to be placed in the wall cavities or sheathing areas so that the overall or "average" wall surface U-value is acceptable.

The U-overall value is calculated by taking the weighted average of the U-values (not R-values) of the different parallel paths through the same component (wall, ceiling or other) that you're dealing with.

6. *System Design*

As an alternative, the system design method can be used so that more insulation is put in the ceiling to make up for the extra windows. However, it is not a one-for-one tradeoff because of the thermal transfer properties and mathematics of reciprocals involved. Let's say you have an R-10 (U = .1) wall and R-10 (U = .1) ceiling of equal area. If you transfer half of the wall insulation, to the ceiling, the wall becomes R-5 (U = .2) and the ceiling becomes R-15 (U = .07). However, you can see that the wall U-value increased by .1 and the ceiling U-value only decreased by .03. (Remember U-values are used to calculate heat losses.)

B. *Heat Loss By Convection*

As mentioned, the other mechanism of heat loss addressed by the UDC is convection, or heat loss by air movement. In homes, this is principally heat loss by exfiltration and infiltration. Exfiltration is the loss of heated air through building cracks and other openings. Infiltration is the introduction of outside cold air into the building. This air movement also causes discomfort (drafts) to occupants in addition to the heat loss itself.

The driving force for this exchange of air is the difference between indoor and outdoor air pressures. Air pressure differences are principally caused by wind pressures and the "stack" effect of warm inside air that tends to rise. Mechanically induced air pressure differences can also occur due to such things as exhaust fans and furnace venting.

To calculate the heat loss by convection, we go back to the general heat loss calculation and modify it to:

$$\text{Air's Heat Capacity} \times \frac{\text{Air Volumed Exchanged}}{\text{Hour}} \times \text{Temp. Difference} = \text{Heat Loss}$$

The volume exchanged can be determined by measuring or judging how many air changes that a house goes through in an hour. For the UDC Energy Worksheet, this is the method used. To do this, you calculate the volume of the heated space and multiply by an air change rate. For a UDC home, you can assume a rate between .25 and .50 air changes per hour, usually with a lower rate for basements with little outside air exposure, and higher rates for living areas or exposed basements. If you have a 1500 *square foot house on a crawl space with 8-foot ceilings, the calculation of the volume exchanged can be:*

$$1500 \text{ sq. ft.} \times 8 \text{ ft.} \times .25 \text{ Air Changes/hr} = 3{,}000 \text{ cu. ft./hr}$$

The heat capacity of air is a physical constant and is .018 BTU per (°F)(cu. ft.). The temperature difference, which varies from 80° to 95° based on Table 22.04-B, used is the same as for heat loss by conduction. So the whole equation for this example is:

$$\frac{.018}{(dF)(cu.\ ft.)} \text{ BTU} \times 3{,}000 \text{ cu. ft./hr.} \times 90^{o} = 4{,}860 \text{ BTUs/hr}$$

This figure is the design or maximum heat loss. If you wanted to figure the total seasonal infiltration heat loss, you would perform a degree day calculation as for the seasonal conduction heat loss calculation. You substitute the seasonal degree days and the 24-hour multiplier for the temperature difference figure in the infiltration heat loss equation above.

Another method of determining heat loss by convection is the crack method. For this method you obtain the air leakage rates in cubic feet per minute for the doors and windows from their manufacturers and multiply by the lineal feet of sash crack or square feet of door area. (A more exact analysis would multiply the door infiltration rates by 1 or 2 due to open/close cycles and add .07 cfm per lineal feet of foundation sill crack.) This gives an air change rate per minute. This has to be converted to an hourly rate by multiplying by 60. Then you substitute this figure for the air change rate in the infiltration heat loss equation above.

C. Total Dwelling Heat Loss

If you add the heat losses by conduction and convection, you arrive at the total dwelling heat loss for purposes of the UDC. Of course this figure is approximate and ignores other means of heat loss. However, it also ignores the major heat gain from secondary sources such as electric lights, human bodies, cooking, etc. So the figure tends to overstate the heat loss but this ensures an adequately sized heating plant.

II. Moisture Control

The second area of concern addressed by the UDC is control of moisture. The occupancy of a dwelling produces a large amount of water vapor. As you may recall from weather forecasts, warmer air can hold more moisture than cold air. In the winter, the inside air is warmer than the outside, so if moisture moving outside by convection or dispersion (similar to conduction) reaches too cold of air, it will "condense out." This occurs at the dew point for that water vapor/air mixture.

This condensation can be damaging to the building if it happens inside part of the wall or ceiling construction. It can promote rotting and lessening of the insulation's R-value.

There are two methods of reducing the possibility of condensation--vapor retarders and cold-side venting.

A. Vapor Retarders

A vapor retarder (sometimes called as a vapor barrier) acts to resist the movement of moisture through a section of the building envelope. A vapor retarder's efficiency at doing so is measured by its permeability in "perms." A perm is one grain of water per (hour) (square foot) (inch of mercury vapor). The lower the number, the more resistant is the material to moisture flowing through it.

The UDC requires a perm rating of one or lower for vapor retarders in nonelectrically heated homes and .1 or lower for electrically heated homes.

For a vapor retarder to work properly, it must be placed on the warm side of the building envelope so moisture does not gain entry into the wall or other building component. The barrier also needs to be continuous with seams and holes lapped or sealed. Otherwise, warm moist air will easily bypass the vapor retarder and enter the wall or ceiling through leaky joints or penetrations. This bypass effect can be substantial.

B. Cold-Side Venting

The other means of controlling moisture is cold-side venting. This is usually employed in attics and unheated crawlspaces. The venting removes excess moisture that bypassed the ceiling vapor retarders or comes out of the earth in the crawl space. This venting is usually done by natural means through the use of grills or louvers from the space to the outside. However, for that to work, there must be high and low venting in the case of the attic or cross ventilation in the case of the crawl space.

Cold-side attic venting also keeps the roof cooler so that there is less melting of snow and creation of ice dams at the eaves in the winter. It also helps dissipate summertime attic heat.

III. Mechanical Ventilation

The next and perhaps more recently developed section of the UDC deals with mechanical ventilation. As the code has mandated tighter home construction, it has had to provide an alternative to infiltration to maintain indoor air quality so excessive humidity or other pollutant levels are checked. This has taken the form of required exhaust ventilation for electrically heated, superinsulated (and tightly built) homes.

A designer may decide to use an air-to-air heat exchanger to satisfy the exhaust requirement, while at the same time recovering heat from the exhausted air. This is done by moving the exhausted air past the intake air with a heat exchanging barrier between the two air streams.

IV. Equipment Sizing and Efficiency Requirements

The final area that Ch. Comm 22 regulates is heating and cooling equipment sizing.

The code requirement is that heating and cooling equipment not exceed the calculated load by more than 15 percent except to satisfy the next manufacturer's model size. The reason for this size limitation is that most equipment designs are such that they are less efficient when used at less than their rated capacity.

In the case of a conventional forced air furnace, each time it shuts down some heat goes up the chimney between the time the furnace goes on and the fan goes on and between the time the fan goes off and the flue damper closes.

This concludes the energy basics section of this commentary chapter.

Subchapter II — Materials and Equipment.

Comm 22.03 Materials, equipment and systems installation.

Comm 22.03 (1) GENERAL. When available, information and values on thermal properties, performance of building envelope sections and components, and heat transfer shall be obtained from the ASHRAE Handbook of Fundamentals.

(2) LABORATORY OR FIELD TEST MEASUREMENTS. (a) *General thermal envelope materials*. When information specified under sub. (1) is not available, or when a different value is claimed, supporting data shall be obtained using one of the following test methods:

a. ASTM C177, Test method by guarded hot plate apparatus.

b. ASTM C236, Standard test method by means of a guarded hot box.

c. ASTM C335, Test method of horizontal pipe insulation.

d. ASTM C518, Test method by means of the heat flow meter apparatus.

e. ASTM C976, Standard test method by means of a calibrated hot box.

(b) *Foam plastic insulation.* 1. When information specified under sub. (1) is not available, or when a different value is claimed, foam plastic insulation that uses a gas other than air as the insulating medium shall use laboratory or field tests conducted on representative samples that have been aged for the equivalent of 5 years or until the R–value has stabilized.

2. The tests shall be conducted by an independent third party using the standards listed under par. (a) and shall be submitted for department review and approval in accordance with s. Comm 20.18.

(c) *Concrete masonry units.* Systems using integrally-insulated concrete masonry units shall be evaluated for thermal performance in accordance with one of the following:

1. Default values as approved by the department with no extrapolations or interpolations.

2. Laboratory or field test measurements specified under par (a).

3. The material approval process specified in s. Comm 20.18.

(3) GENERAL INSTALLATION. (a) Materials, equipment and systems shall be identified in a manner that will allow a determination of their compliance with the applicable provisions of this chapter.

(b) All insulation materials, caulking and weatherstripping, fenestration assemblies, mechanical equipment and systems components, and water-heating equipment and system components shall be installed in accordance with the manufacturer's installation instructions.

(c) Manufacturer's installation instructions shall be available on the job site at the time of inspection.

(4) DWELLING ENVELOPE INSULATION. (a) Except as provided in par. (b), a thermal resistance identification mark shall be applied by the manufacturer to each piece of dwelling envelope insulation 12-inches or greater in width.

(b) Insulation without a thermal resistance identification mark may be used if the insulation installer provides a signed and dated certification for the insulation installed in each element of the building envelope, listing the type of insulation, the manufacturer and the R-value. For blown-in or sprayed insulation, the installer shall also provide the initial installed thickness, the calculated settled thickness, the coverage area and the number of bags installed. The installer shall post the certification in a readily accessible conspicuous place on the job site.

(5) INSULATION INSTALLATION. (a) Roof and ceiling, floor and wall cavity batt or board insulation shall be installed in a manner which will permit inspection of the manufacturer's R-value identification mark.

(b) The thickness of roof and ceiling insulation that is either blown in or sprayed shall be identified by thickness markings that are labeled in inches installed at least one for every 300 square feet through the attic space. The markers shall be affixed to trusses or joists marking the minimum initial in-stalled thickness and minimum settled thickness with numbers a minimum of one-inch in height. Each marker shall face the attic access. The thickness of installed insulation shall meet or exceed the minimum initial installed thickness shown by the marker.

Comm 22.04 Protection of insulation.

(1) BLANKET INSULATION. Except in the box sill, insulating blankets or batts shall be held in place with a covering or other means of mechanical or adhesive fastening.

Note: Acceptable covering or fastening for interior or warm-side applications includes drywall, vapor retarder material, foil or kraft paper backing or other means of holding the blankets in place. Air barrier material may be used for cold-side support.

(2) FOAM PLASTIC INSULATION. Exterior foam plastic insulation shall be protected from physical damage and damage from ultraviolet light.

Note: For interior applications, a thermal barrier may be required under s. Comm 21.11.

Comm 22.05 Fenestration product rating certification and labeling.

(1) CERTIFIED PRODUCTS. Except as provided in sub. (2), fenestration product rating, certification and labeling, U-values of windows, doors and skylights shall be determined in accordance with the National Fenestration Rating Council standard 100, Procedures for Determining Fenestration Product Thermal Properties, by an accredited, independent laboratory. Fenestration products shall be labeled and certified by the manufacturer. Such certified and labeled values shall be accepted for purposes of determining compliance with the dwelling envelope requirements of this code.

(2) DEFAULT VALUES. When a manufacturer has not determined product U-value in accordance with NFRC 100 for a particular product line, compliance with the dwelling envelope requirements of the code shall be determined by assigning such products a default U-value in accordance with Tables 22.05-1 and 22.05-2. Product features must be verifiable for the product to qualify for the default value associated with those features. Where the existence of a particular feature cannot be determined with reasonable certainty, the product shall not receive credit for that feature. Where a composite of materials of two different product types is used, the product shall be assigned the higher U-value.

Different types of window operating hardware will produce different U-values for similar-sized windows. Therefore, a 3'-0" x 3'-0" double hung window would have a different U-value from a 3'-0" x 3'-0" fixed window sash. Similar size windows produced by two different manufacturers would most likely also have different U-values.

TABLE 22.05-1

U-VALUE DEFAULT TABLE FOR WINDOWS, GLAZED DOORS AND SKYLIGHTS*

	Single Glazed	Double Glazed
METAL WITHOUT THERMAL BREAK		
Operable	1.27	0.87
Fixed	1.13	0.69
Garden Window	2.60	1.81
Curtain Wall	1.22	0.79
Door	1.26	0.80
Skylight	1.98	1.31
Site Assembled Skylight	1.36	0.82
METAL WITH THERMAL BREAK		
Operable	1.08	0.65
Fixed	1.07	0.63
Curtain Wall	1.11	0.68
Door	1.10	0.66
Skylight	1.89	1.11
Site Assembled Skylight	1.25	0.70
REINFORCED VINYL OR METAL-CLAD WOOD		
Operable	0.90	0.57
Fixed	0.98	0.56
Door	0.99	0.57
Skylight	1.75	1.05
WOOD/VINYL/FIBERGLASS		
Operable	0.89	0.55
Fixed	0.98	0.56
Garden Window	2.31	1.61
Door	0.98	0.56
Skylight	1.47	0.84

* Glass block assemblies shall have a default U-value of 0.60.

TABLE 22.05-2
U-VALUE DEFAULT TABLE FOR NON-GLAZED DOORS

STEEL DOORS (1-3/4 inches thick)	**With Foam Core**	**Without Foam Core**
	0.35	0.60
WOOD DOORS (1-3/4 inches thick)	**Without Storm Door**	**With Storm Door**
Panel with 7/16-inch panels	0.54	0.36
Hollowcore flush	0.46	0.32
Panel with 1-1/8-inch panels	0.39	0.28
Solid core flush	0.40	0.26

Subchapter III — Definitions.

Comm 22.06 Definitions.

In ch. Comm 22:

(1) "Accessible", as applied to equipment, means admitting close approach to equipment not guarded by locked doors, elevation or other effective means.

Note: See "readily accessible".

(2) "Air conditioning" means the process of treating air to control simultaneously its temperature, humidity, cleanness, and distribution to meet the requirements of the conditioned space.

(3) "Automatic" means self-acting, operating by its own mechanism when actuated by some impersonal influence, such as a change in current strength, pressure, temperature or mechanical configuration.

(4) "Basement wall" is the opaque portion of a wall that encloses one side of a basement and is partially or totally below grade.

(5) "Conditioned space" means space within the dwelling envelope which is provided with heated or cooled air or surfaces to provide a heated space or a cooled space.

(6) "Cooled space" means a space directly or indirectly supplied with mechanical cooling to maintain air temperature within the space of 85°F or less at design conditions.

(7) "Crawl space wall" means the opaque portion of a wall which encloses a crawl space and is partially or totally below grade.

(8) "Deadband" means the range of values within which an input variable can be varied without initiating any noticeable change in the output variable.

(9) "Dwelling envelope" means the elements of a dwelling with enclosed conditioned space through which thermal energy may be transferred to or from the exterior.

(10) "Electrically heated" means provided with permanently installed electrical space heating equipment which has an input capacity of 3 kilowatts or more to meet all or part of the space heating requirements.

(11) "Energy" means the capacity for doing work, taking a number of forms which may be transformed from one form into another, such as thermal heat, mechanical work, electrical and chemical in customary units, measured in kilowatt-hours (kWh) or British thermal units (Btu).

Note: See "New energy".

(12) "Energy, Recovered". See "Recovered energy".

(13) "F-value" means the rate of heat loss through a slab per foot of perimeter measured in Btu/h • ft • °F.

(15) "Gross exterior wall area" means the normal projection of the dwelling envelope wall area bounding interior space which is conditioned by an energy-using system including opaque wall, window and door area. The gross area of exterior walls consists of all opaque wall areas, including between floor spandrels, box sills, window area including sash, and door areas when they are exposed to outdoor air or unconditioned spaces and enclosed heated or mechanically cooled space, including interstitial area between two such spaces. The gross exterior wall area includes the total basement wall area if it is less than 50 percent below grade. The gross exterior wall area includes non-opaque areas such as windows and doors of all basement walls. Any skylight shaft walls that are 12 inches or more in depth, measured from the ceiling plane to the roof deck, shall be considered in the gross area of exterior walls d are excluded from consideration in the roof assembly.

(16) "Gross floor area" means the sum of areas of all floors of the structure, including basements, cellars, and intermediate floored tiers measured from the exterior faces of exterior walls or from the center line of interior walls, excluding covered walkways, open roofed-over areas, porches, pipe trenches, exterior terraces or steps, chimneys, roof overhangs and similar features.

(17) "Heat" means energy that is transferred by virtue of a temperature difference or a change in state of a material.

(18) "Heated slab" means slab-on-grade construction in which the heating elements or hot air distribution system is in contact with or placed within the slab or the subgrade.

(19) "Heated space" means any enclosed space provided with a direct or indirect supply of heat to maintain the temperature of the space to at least 50° F at design conditions.

(20) "Humidistat" means a regulating device, actuated by changes in humidity, used for automatic control of relative humidity.

(21) "HVAC" means heating, ventilating and air conditioning.

(22) "HVAC system" means the equipment, distribution network, and terminals that provide either collectively or individually the processes of heating, ventilating, or air conditioning to a building.

(23) "Infiltration" means the uncontrolled inward air leakage through cracks and interstices in any dwelling element and around windows and doors of a dwelling caused by the pressure effects of wind, and the effect of differences in the indoor and outdoor air density.

(24) "Inherently protected type IC" means tested and listed by an independent testing laboratory as being suitable for installation in a cavity where the fixture may be in direct contact with thermal insulation or combustible materials and the fixture construction is such that, even without a thermal protector, the fixture cannot be overlamped or mislamped.

(25) "Manual" means capable of being operated by personal intervention.

Note: See "Automatic".

(26) "New energy" means energy other than recovered energy, utilized for the purpose of heating or cooling.

Note: See "Energy".

(27) "Opaque areas" means all exposed areas of a dwelling envelope which enclose conditioned space except openings for windows, skylights, doors and dwelling service systems.

(28) "Readily accessible" means capable of being reached quickly for operation, renewal or inspections, without requiring a person to climb over or remove obstacles or to resort to portable ladders or access equipment.

Note: See "Accessible".

(29) "Recovered energy" means energy utilized which would otherwise be wasted and would not contribute to a desired end use, from an energy utilization system.

(30) "Renewable energy sources" means sources of energy, excluding minerals, derived from incoming solar radiation, including natural daylighting and photosynthetic processes: from phenomena resulting therefrom, including wind, waves and tides, lake or pond thermal differences and from the internal heat of the earth, including nocturnal thermal exchanges.

(31) "Roof assembly" means all components of the roof and ceiling envelope through which heat flows, thus creating a building transmission heat loss or gain, where such assembly is

exposed to outdoor air and encloses a heated or mechanically cooled space. The gross area of a roof assembly consists of the total interior surface of all roof or ceiling components, including opaque surfaces, dormer and bay window roofs, treyed ceilings, overhead portions of an interior stairway to an unconditioned attic, doors and hatches, glazing and skylights exposed to conditioned space, that are horizontal or sloped at an angle less than 60 degrees from the horizontal. A roof assembly, or portions thereof, having a slope of 60 degrees or greater from horizontal shall be considered in the gross area of exterior walls and shall be excluded from consideration in the roof assembly. Any skylight shaft walls less than 12 inches in depth, as measured from the ceiling plane to the roof deck, shall be considered in the roof assembly and are excluded from consideration in the gross area of exterior walls.

(32) "Sequence" means a consecutive series of operations.

(33) "Service systems" means all energy-using systems in a dwelling that are operated to provide services for the occupants or processes housed therein, including HVAC, service water heating, illumination, transportation, cooking or food preparation, laundering and similar functions.

(34) "Service water heating" means a supply of hot water for purposes other than comfort heating.

(35) "Service water heating demand" means the maximum design rate of energy withdrawal from a service water heating system in a designated period of time; usually an hour or a day.

(36) "Slab-on-grade floor insulation" means insulation around the perimeter of the floor slab or its supporting foundation.

(37) "Solar energy source" means a source of natural daylighting and of thermal, chemical or electrical energy derived directly from conversion of incident solar radiation.

(38) "System" means a combination of central or terminal equipment and their components, controls, accessories, interconnecting means, and terminal devices by which energy is transformed so as to perform a specific function such as, HVAC, service water heating or illumination.

(39) "Thermal conductance" means the time rate of heat flow through a body, frequently per unit area, from one of its bounding surfaces to the other for a unit temperature difference between the two surfaces, under steady state conditions. It is expressed as Btu/h • ft^2 • °F.

(40) "Thermal resistance" or "R" means a measure of the ability to retard the flow of heat. The R-value is the reciprocal of thermal transmittance or U-Value expressed as R= 1/U.

Note: The higher the R-value of a material, the more difficult it is for heat to be transmitted through the material.

(41) “Thermal resistance overall” or “R_o” means the reciprocal of overall thermal conductance expressed as Btu/h • ft^2 • °F. The overall thermal resistance of the gross area or individual component of the exterior dwelling envelope such as, roof and ceiling, exterior walls, floors, crawl space walls, foundation walls, windows, skylights, doors, and opaque walls, includes the weighted R-values of the component assemblies, including air-film, insulation, drywall, framing, and glazing.

(42) “Thermal transmittance” or “U” means the time rate of heat flow through a body or assembly which is located in between 2 different environments, expressed in Btu/h • $ft.^2$ • °F. The U-value applies to combinations of different materials used in series along the heat flow path and also to single materials that comprise a dwelling section, including cavity air spaces and air films on both sides of a dwelling element.

Note 1: The lower the U-value of a material, the more difficult it is for heat to be transmitted through the material.

Note 2: The thermal transmittance is also referred to as the coefficient of heat transfer or the coefficient of heat transmission.

(43) “Thermal transmittance overall” or “U_o” means the overall, average heat transmission of a gross area of the exterior dwelling envelope expressed as Btu/h • ft^2 • °F. The U_o-value applies to the combined effect of the time rate of heat flow through various paths, such as windows, doors and opaque construction areas, comprising the gross area of one or more exterior dwelling components, such as walls, floors or roof and ceilings.

(44) “Thermally protected type IC ” means tested and listed by an independent testing laboratory as being suitable for installation in a cavity where thermal insulation will be in direct contact with the fixture.

(45) “Thermostat” means an automatic control device actuated by temperature and designed to be responsive to temperature.

(46) “Ventilation” means the process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.

(47) “Zone” means a space or group of spaces within a dwelling with heating or cooling requirements sufficiently similar so that comfort conditions can be maintained throughout by a single controlling device.

Subchapter IV — Design Criteria

Comm 22.07 Indoor and outdoor temperatures.

(1) GENERAL. The indoor temperatures listed in sub. (2) and the outdoor temperatures listed in Table 22.07 shall be used to determine the total dwelling heat loss and to select the size of the of the heating equipment.

(2) INDOOR DESIGN TEMPERATURES. Unheated, non-habitable basement areas shall use a design temperature of less than 50°F. All other areas of a dwelling shall use a design temperature of 70°F.

TABLE 22.07

OUTDOOR DESIGN CONDITIONS BASED ON FIGURE 22.07

Zone 1	25^{o} below zero F
Zone 2	20^{o} below zero F
Zone 3	15^{o} below zero F
Zone 4	10^{o} below zero F

Note: See Figure 22.07 for zone boundaries.

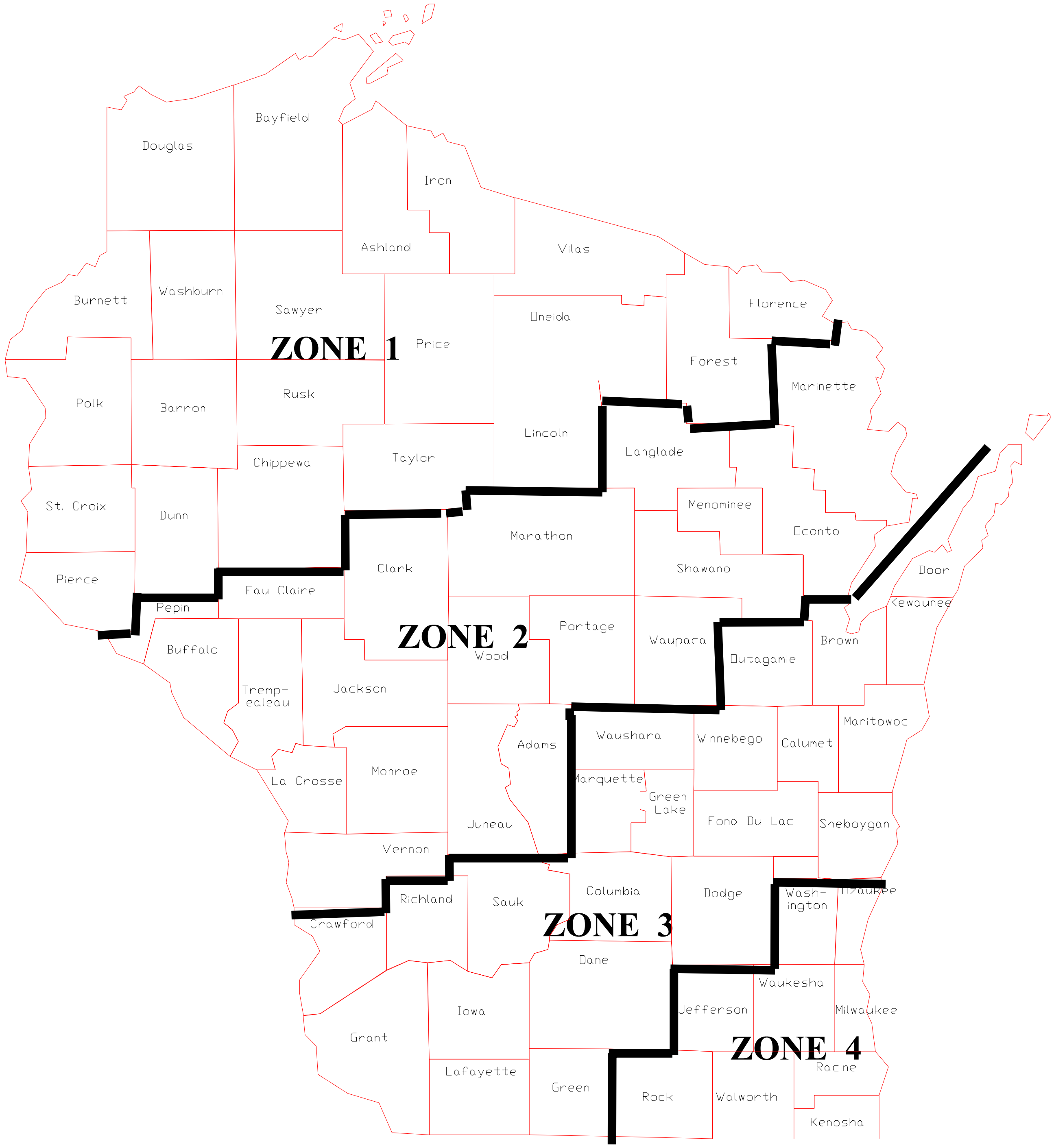

ZONE 1
ZONE 2
ZONE 3
ZONE 4
Douglas
Bayfield
Iron
Ashland
Vilas
Burnett
Washburn
Sawyer
Price
Oneida
Florence
Forest
Marinette
Polk
Barron
Rusk
Lincoln
Langlade
Taylor
Chippewa
St. Croix
Dunn
Menominee
Oconto
Marathon
Shawano
Clark
Pierce
Eau Claire
Pepin
Door
Kewaunee
Portage
Waupaca
Outagamie
Brown
Wood
Buffalo
Tremp-
ealeau
Jackson
Adams
Waushara
Winnebego
Calumet
Manitowoc
Monroe
La Crosse
Marquette
Green
Lake
Fond Du Lac
Sheboygan
Juneau
Vernon
Richland
Sauk
Columbia
Dodge
Wash-
ington
Ozaukee
Crawford
Dane
Waukesha
Iowa
Jefferson
Milwaukee
Grant
Racine
Lafayette
Green
Rock
Walworth
Kenosha

FIGURE 22.07

Comm 22.08 Ventilation and moisture control.

(1) ATTICS. (a) Ventilation shall be provided above the ceiling or attic insulation. At least 50% of the net free ventilating area shall be distributed at the low sides of the roof. The remainder of the net free ventilating area shall be distributed in the upper one-half of the roof or attic area.

1. If more than 50%, but less than 75% of the net free ventilating area is provided at the low sides of the roof, the total net free ventilating area shall be a minimum of 1/300 of the horizontal area of the ceiling.

2. If 75% or more of the net free ventilating area is provided at the low sides of the roof, the total net free ventilating area shall be at least 1/150 of the horizontal area of the ceiling.

(b) As an exception to par (a), the ventilation space above any non-rigid insulation in a cathedral ceiling assembly shall be at least one inch in height.

(c) Engineered systems that provide equivalent ventilation to that specified in par. (a) may be used.

(d) The ventilation area required in par. (a) shall be maintained after the installation of insulation.

(2) CRAWL SPACES. Ventilation shall be provided in crawl spaces which are outside the dwelling envelope. The area of ventilation shall be at least 1/1500 of the floor space. At least 50% of the ventilating area shall be provided at opposite sides of the crawl space or as far apart as possible.

(3) CLOTHES DRYERS. If clothes dryers are provided, the dryers shall be vented to the outside of the dwelling. The dryer vents may not terminate in an attic space or crawl space or basement.

Note: See s. Comm 23.14 for vent material requirements.

Subchapter V — Heating and Air Conditioning Equipment and Systems

Comm 22.09 Scope.

This subchapter covers the determination of system heating and cooling loads, design requirements, system and component performance, control requirements, and distribution system construction and insulation.

Comm 22.10 Calculating heating and cooling loads.

The design requirements specified in Subchapter IV shall apply for all computations.

Comm 22.11 Calculation procedures.

(1) Heating and cooling design loads including ventilation loads for the purpose of sizing systems shall be determined in accordance with one of the procedures described in Chapter 25 of ASHRAE Handbook of Fundamentals.

(2) Infiltration for heating and cooling design loads shall be calculated based on a maximum of 0.5 air change per hour in the heated or cooled space.

Comm 22.12 Selection of equipment.

(1) GENERAL. Except as provided in sub. (2), the output capacity of the mechanical heating equipment shall not exceed the calculated heating load by more than 15%, except to satisfy the manufacturer's next closest nominal size.

(2) WATER HEATERS USED FOR SPACE HEATING. The output capacity of water heaters that are used for simultaneous space heating shall exceed the calculated space heating load by at least 43%, but by no more than 49%. Other sizing methods may be used if approved by the department for water heaters providing simultaneous space and domestic water heating.

Note: Heat exchanger units that are part of the plumbing system shall meet the requirements of Chs. Comm 81-84.

(3) The efficiency of equipment installed in a dwelling shall match the efficiency used to claim any credit under the method of design by system analysis or other approved compliance method.

Comm 22.13 Supplementary heater for heat pumps.

(1) If a heat pump is installed, it shall include a control to prevent supplementary heater operation when the operating load can be met by the heat pump alone.

(2) Supplementary heater operation is permitted during transient periods, such as start-up periods, following room thermostat set-point advance, and during defrost periods.

(3) A two-stage thermostat, which controls the supplementary heat on its second stage, shall be accepted as meeting this requirement. The cut-on temperature for the compression heating shall be higher than the cut-on temperature for the supplementary heat. Supplementary heat may be derived from any source including, electric resistance, combustion heating, and solar stored-energy heating.

Comm 22.14 Mechanical ventilation.

(1) Mechanical ventilation system supply and exhaust shall be equipped with a readily accessible means for shutoff when ventilation is not required.

(2) Automatic or gravity dampers that close when the system is not operating shall be provided for outdoor air intake and exhaust.

Comm 22.15 Temperature control

(1) A readily accessible manual or automatic means shall be provided to restrict or shut off the heating or cooling input to each zone or floor.

(2) Each system shall be provided with an adjustable thermostat for the regulation of temperature. A thermostat shall be capable of being set by adjustment or selection of sensors as follows:

(a) When used to control heating only, the thermostat shall be capable of being set from 55°F to 75°F.

(b) When used to control cooling only, the thermostat shall be capable of being set from 70°F to 85°F.

(c) When used to control both heating and cooling, the thermostat shall be capable of being set from 55°F to 85°F and shall be capable of operating the system heating and cooling in sequence. The thermostat or control system shall have an adjustable deadband of at least 10°F.

Comm 22.16 Humidity control.

If a system is equipped with a means for adding or removing moisture to maintain a selected relative humidity in spaces or zones, a humidistat shall be provided.

(1) Humidistats of humidifiers shall be capable of being set to prevent new energy from being used to produce a space or zone relative humidity above 30 percent.

(2) Humidistats of dehumidifiers shall be capable of being set to prevent new energy from being used to produce a space or zone relative humidity of less than 60 percent.

Note: This requirement does not restrict the actual operation of the equipment. The only requirement is that the specified setpoints be available to the occupants so that they can minimize energy consumption. The controls are not limited to the specified settings alone.

Comm 22.17 Duct system insulation.

(1) Except as provided in sub. (4), all heating and cooling duct systems, or portions thereof, that are located in unheated or uncooled spaces respectively, shall be provided with insulation with a thermal resistance of at least R-5.

Note: Where control of condensation is required for compliance with s. Comm 22.22, additional insulation, vapor retarders, or both, may need to be provided to limit vapor transmission and condensation.

(2) Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of this section or s. Comm 22.21.

(3) Insulation resistance shall be measured on a horizontal plane in accordance with ASTM standard C 518 at a mean temperature of 75°F at the installed thickness

(4) Duct insulation, except as required to prevent condensation, is not required on any of the following ducts:

(a) Supply-air or return-air ducts that are installed in basements, cellars or unventilated crawl spaces having insulated walls.

(b) Ducts for which heat gain or loss, without insulation, will not increase the energy requirements of the building.

(c) Ducts located within HVAC equipment.

(d) Exhaust air ducts.

Comm 22.18 Duct and plenum sealing.

(1) Sections of supply and return ducts not located entirely within the conditioned space and the unconditioned side of enclosed stud bays or joist cavities or spaces used to transport air shall be sealed.

(2) Sealing shall be accomplished using welds, gaskets, mastics, mastic-plus-embedded-fabric systems or tapes installed in accordance with the manufacturer's instructions.

(3) Insulation that provides a continuous air barrier may be used in lieu of sealing metal ducts.

(4) Tapes and mastics used with rigid fibrous glass ducts shall be listed and labeled as complying with UL 181A.

(5) Tapes and mastics used with flexible air ducts shall be listed and labeled as complying with UL 181B.

(6) Tapes with rubber-based adhesives may not be used.

Note: Standard duct tape has a rubber-based adhesive and does not comply with the requirements of this section.

Comm 22.19 Pipe insulation.

(1) Except as provided in sub. (2), all heating pipes in unheated spaces and all cooling pipes in uncooled spaces shall be insulated with material providing a minimum thermal resistivity of R-4 as measured on a flat surface in accordance with ASTM standard C 335 at a mean temperature of 75 °F.

(2) Piping insulation is not required in any of the following cases:

(a) Pipes installed within heating and air conditioning equipment, installed in conditioned spaces.

(b) Piping at fluid temperatures between 55°F and 120°F when not required for energy conservation purposes.

(c) When the heat loss or gain of the piping without insulation does not increase the energy requirements of the dwelling.

(d) When piping is installed in basements, cellars or unventilated crawl spaces having insulated walls.

Note: Additional insulation and vapor retarders may be necessary to prevent condensation in accordance with s. Comm 22.22.

Subchapter VI — Dwelling Envelope Design

Comm 22.20 General.

(1) APPLICATION. The dwelling envelope of all 1- and 2-family dwellings shall comply with this subchapter, unless the requirements of system analysis design of subch. VII are met.

(2) PRESCRIPTIVE PATH FOR ADDITIONS. (a) As an alternative to demonstrating compliance with ss. Comm 22.23 to 22.28, dwelling additions with a conditioned floor area less than 500 square feet shall meet the prescriptive envelope component criteria in Table 22.20.

(b) The U-factor of each individual fenestration product shall be used to calculate an area-weighted average fenestration product U-factor for the addition, which may not exceed the listed values in Table 22.20.

(c) The total area of fenestration products may not exceed 25 percent of the gross exterior wall area of the addition.

(d) The R-values for opaque thermal envelope components shall be equal to or greater than the applicable listed values in Table 22.20.

TABLE 22.20
PRESCRIPTIVE ENVELOPE COMPONENT CRITERIA FOR ADDITIONS TO AND REPLACEMENT WINDOWS FOR EXISTING SINGLE-FAMILY DWELLINGS

DESIGN ZONE [a]	MAXIMUM	MINIMUM					
	Fenestration U-factor [b, c]	Ceiling R-value [d]	Wall R-value	Floor R-value [d]	Basement wall R-value [e]	Slab perimeter R-value and depth [f]	Crawl space wall R-value [g]
2-4	0.35	R-38	R-21	R-21	R-11	R-13,4 ft.	R-20
1	0.35	R-38	R-21	R-21	R-19	R-18, 4 ft.	R-20

a. Refer to Figure 22.07 for design zone boundaries.
b. Exception: replacement skylights shall have a maximum U-factor of 0.50.
c. Fenestration shall meet s. Comm 22.05.
d. Floors over outside air shall meet Ceiling R-value requirements.
e. Basement wall insulation shall be installed in accordance with s. Comm 22.28.
f. Slab perimeter insulation shall be installed in accordance with s. Comm 22.26. An additional R-2 shall be added to Slab perimeter R-value in the table if the slab is heated.
g. Crawl space wall R-value shall apply to unventilated crawl spaces only. Crawl space insulation shall be installed in accordance with s. Comm 22.27.

Note: See appendix for a copy of the UDC Energy Worksheet used to show compliance with the envelope insulation requirements of ss. Comm 22.21 to 22.28. Copies of the worksheets may be obtained from the Department of Commerce, Safety & Buildings Division, P.O. Box 2509, Madison, WI 53701. Other forms or software may be used when approved by the department. WIScheck software may be used to show compliance and is available from the Safety & Buildings page on the Department of Commerce Website www.commerce.state.wi.us.

Comm 22.21 Envelope requirements.

(1) GENERAL. (a) The stated U_o- , U- or R-value of an assembly may be increased or decreased, provided the total thermal transmission heat gain or loss for the entire dwelling does not exceed the total U_o- ,U- or R-value of an assembly resulting from conformance to the values specified in ss. Comm 22.23 to 22.28.

(b) Where basement and crawl space walls are part of the building envelope, their U-factors shall be based on the wall components and surface air films. Adjacent soil may not be considered in the determination.

Note: Foundation insulation techniques can be found in the DOE Building Foundation Design Handbook.

(2) APPLICATION OF STANDARDS FOR ELECTRICALLY HEATED DWELLINGS. (a) New dwellings. New dwellings that are electrically heated shall meet the thermal performance standards of this subchapter for electrically heated dwellings.

(b) Additions. If the combined input capacity of permanently installed electrical space heating equipment of the original dwelling and a new addition exceeds 3 kilowatts, either the addition shall meet the thermal performance standards of this subchapter for electrically heated dwellings or the entire dwelling and addition shall meet the thermal performance standards of this subchapter for electrically heated dwellings.

(c) Alterations. If an alteration results in the addition of permanently installed electrical space heating equipment with a combined input capacity of permanently installed electrical space heating equipment of the altered dwelling exceeds 3 kilowatts, either the area served by the new electrical space heating equipment shall meet the thermal performance standards of this subchapter for electrically heated dwellings or the entire dwelling, and the addition shall meet the thermal performance standards of this sub-chapter for electrically heated dwellings.

(3) APPLIANCE CREDITS. The maximum overall heat loss allowance may be increased when an equivalent amount of energy savings is provided by the following types of high efficiency heating equipment:

(a) A furnace with an AFUE of 90% or greater.

(b) A boiler with an AFUE of 81% or greater.

Note: AFUE means annual fuel utilization efficiency.

(c) An air-source heat pump with an HSPF of 7.8 or greater.

Note: HSPF means heating seasonal performance factor.

(d) A geothermal heat pump.

(e) A radiant electric heat panel that meets all of the following requirements:

1. The panel delivers at least 50% of its heat output by radiation.

2. The panel reaches its operating temperature in 15 minutes or less.

3. a. The panel is surface mounted.

b. The panel is not located behind finish material, such as paneling or carpeting and is not located within a wall, floor or ceiling assembly.

Note: The UDC Energy Worksheet and WIScheck software will determine the amount of credit available.

TABLE 22.21
HEATING AND COOLING CRITERIA [g]

	Maximum Overall Thermal Transmittance, U_0 or Minimum Thermal Resistance, R	
Component of Dwelling Envelope	**Non-electrically Heated**	**Electrically Heated**
Roof and Ceiling[a]	$U_0 = 0.026$	$U_0 = 0.020$
Walls:		
crawl space[c, f]	$U_0 = 0.060$	$U_0 = 0.060$
basement[c, f]	$U_0 = 0.091$	$U_0 = 0.091$
walls[b]	$U_0 = 0.110$	$U_0 = 0.080$
Floors:		
heated slab-on-grade[c, d,f].	R = 8.5	R = 10
over unheated space[e]	$U_0 = 0.050$	$U_0 = 0.050$
unheated slab-on-grade[c, d,f]	R = 6.5	R = 10
over outside air (overhang)	$U_0 = 0.033$	$U_0 = 0.033$

[a] Roof and ceiling assemblies include attic access panels and skylights.
[b] See definition of gross exterior wall area.
[c] Insulation installed below grade shall be suitable for that application.
[d] "Heated slab" means slab-on-grade construction in which the heating elements or hot air distribution system is in contact with or placed within the slab or the subgrade. The required U-value refers to the insulation only.
[e] Includes unheated crawl spaces, basements, garages, and other spaces outside of the dwelling envelope.
[f] The required U-value applies to the floor or wall assembly only, excluding the effect of soil.

Comm 22.22 Vapor retarders.

(1) GENERAL. (a) Designs shall prevent deterioration from moisture condensation.

(b) Vapor retarders shall have a rating of 1.0 perm or less when tested in accordance with ASTM standard E 96, Procedure A.

(c) The vapor retarder shall be continuous. All joints in the vapor retarder shall be overlapped and secured or sealed. Rips and punctures in the vapor retarder shall be patched with vapor retarder materials and taped or sealed.

(2) FRAME ASSEMBLIES. In all frame walls, floors and ceilings, the vapor retarder shall be installed on the warm side of the thermal insulation. The vapor retarder shall cover the exposed insulation and the interior face of studs, joists and rafters. No vapor retarder is required in the box sill.

(3) CONCRETE FLOORS. A vapor retarder shall be installed under the slab or under the base course of slabs and basement floors unless the slab is in an unheated attached garage

(4) CONCRETE OR MASONRY BASEMENT WALLS. A vapor retarder is not required in concrete or masonry basement wall below-ground applications.

(5) CRAWL SPACES. A vapor retarder shall be provided over crawl space floors in accordance with s. Comm 21.05 (4).

(6) WOOD FOUNDATIONS. Vapor retarders for wood foundations shall be in accordance with the standards adopted under s. Comm 20.24, Table 20.24-2 2.

Vapor Retarders

The requirement for a vapor retarder in ceilings and walls prevents deterioration of the wood structural members caused by condensation within the wall cavities or ceiling cavity. Vapor condenses when it comes in contact with material that is at a temperature lower than its dew point. The vapor retarder is required to keep the moisture out of the insulated wall cavities where the dew point temperature is reached. This temperature typically occurs within the wall cavity and thus would condense out water vapor before it can escape from the dwelling. If condensation is occurring on the interior surfaces of the dwelling, it is occurring at points where the buildings materials are cooler than the vapor's dew point. This situation is usually first evident on windows where the glass provides a colder surface on which condensation can occur.

Additional areas where condensation occurs are generally at corners of rooms at the exterior walls. This area is subject to condensation for a number of reasons. The temperature at the corners is generally cooler due to the fact that it is difficult to insulate at this location due to the method of construction. The insulation may be further reduced due to the roof system allowing less insulation to be placed above the corner. Condensation also occurs in areas with poor air circulation such as closets.

Recent studies have shown that air infiltration may be the greatest cause of condensation. At the corners of the walls is the area with the greatest potential to obtain air infiltration if precautions are not taken at the time of construction. The vapor retarder installed may not be complete at the corners due to the meeting of the ceiling and wall area. This allows additional moisture to pass through the corners and to be subject to condensation.

When condensation occurs, an environment is now created that is conducive to the formation of mold. This could occur on the surface or with wall/ceiling cavities. Elimination of the vapor retarder requirements at the interior finish would only allow the condensation, mold formation and deterioration of the wood to occur within the structural elements of the dwelling. Proper precautions during the original construction stages are generally adequate to prevent condensation from occurring. In some cases where the lifestyle of the inhabitants of the dwelling is such that a large quantity of humidity is produced, an occasional airing out of the dwelling by exhaust fans or opening windows should be employed by the occupants. Such ventilation may also be necessary when homes are built especially tight and natural infiltration is low.

Moisture Control During Construction

Unless proper construction techniques are utilized during construction, serious problems can occur as a result of water vapor that is trapped inside and then causes deterioration of dry wall.

Over the years we have seen many improvements in both materials and methods in home construction. Often times the use of a new material required the change in a technique or method of construction previously unheard of. Most building codes are only a reflection of our latest achievements in technology and engineering. The vapor retarder requirements in the Uniform Dwelling Code are a reflection of state of the art insulation techniques. Simply stated, the purpose of the vapor retarder is to prevent (as much as possible) water vapor from penetrating into the insulation and thereby reducing the effectiveness of the insulation. The problem is that builders who are not familiar with the use of vapor retarders, particularly during winter construction months, can inadvertently create problems for the homeowner if precautionary measures are not taken during construction. We offer the following suggestions to incorporate in construction procedures, especially during winter months:

1. *Do not allow drywall to pick up excess moisture prior to installation.*

2. *Make sure attics are insulated prior to putting heat into the home for drywall taping and finishing. Many builders neglect to do this and create condensation problems when the water vapor condenses upon hitting the cold, attic air above the dry wall. Drywall ceilings should be hung and insulated prior to putting heat into the home.*

3. *Make sure all heating appliances, i.e., furnaces, temporary heaters, salamanders, etc., are vented to the outside of the home. Builders who do not follow this warning are adding additional water vapor created by combustion of heating fuels.*

4. *Make sure all required attic ventilation is installed and operable to remove any water vapor trapped in the attic.*

5. *Provide a means for the water vapor in the home to escape; such as periodic opening of windows, doors, etc. Perhaps the installation of a humidistatically controlled exhaust fan is necessary, particularly where electric baseboard heat or heat pump systems are utilized.*

6. *Do not overload drywall ceilings with insulation beyond their capacity. See s. Comm 21.02 (1)(a) of this commentary.*

Incorporation of these techniques will avoid major problems with condensation. These methods are not new and have been proven successful by many hundreds of builders operating in climates such as ours.

<u>"Post-Construction" Moisture Control Problems</u>

As discussed in the basics section of this commentary chapter, moisture must be dealt with in all homes. The following is a general discussion of typical symptoms, causes and prevention techniques regarding moisture problems in homes. It is intended as background information to help explain some UDC requirements. Additional recommendations above and beyond the UDC minimums are included for homeowners who may experience more severe moisture problems.

I. HOW CAN YOU DETERMINE IF A HOME HAS A MOISTURE PROBLEM?

You can get a good idea of whether your home has an excess moisture problem that may lead to damage by checking for the following symptoms.

A. Extensive condensation on windows during the heating season. Some condensation is normal. Condensation that streams off the window and puddles on the frame and sill when outside temperatures are 10°F or above and inside temperatures are above 65°F indicates humidity levels are probably too high.

1. If condensation is limited to the inside surface of storm windows, then your primary windows may be allowing moist interior air to leak by them. Because of the "stack" pressure effect, this problem may be worse on second floor windows.

If condensation is limited to the inside surface of the primary windows, then your storm windows may be allowing cold air to leak by them which then cools the primary window.

B. Staining and mold on window frames.

C. Mold or water spots in numerous locations on the inside surface of outside walls. Common trouble spots include closets on outside walls; corners between two outside walls or between an outside wall and ceiling; and outside walls behind furniture; or other areas where air circulation is limited.

D. Soft or buckling interior wall surfaces. Drywall is a common interior surface. When dampened it may pull away from studs or ceiling rafters. Additional moisture may cause the drywall to crumble.

E. Staining or warping of exterior siding.

F. Paint peeling from exterior siding, especially extensive peeling of paint down to the primer.

If you have not experienced any of these symptoms, the home probably does not have a moisture problem. However, it may be a good idea to consider some of the measures in the following Section III to assure that future problems do not develop.

II. WHAT ARE TYPICAL CAUSES OF MOISTURE PROBLEMS IN HOMES?

Through breathing and normal daily activities, each member of a household produces about seven pounds of water vapor. Naturally this number varies greatly depending on living habits. This water vapor becomes part of the air. However, air can hold only a limited amount of water vapor. This amount depends on temperature. The higher the temperature the more moisture the air can hold. When more moisture is introduced into the air than it can hold, some of the moisture will condense on surfaces. If cold surfaces sufficiently cool the surrounding air, condensation will occur on that surface even though the remaining room air is not saturated with moisture. The frosted cold beverage glass in summer is an example.

In most older homes there is enough movement of air into and out of the house that moisture does not build up and only small amounts of condensation occurs. However, when air leaks into and out of a house it not only takes moisture but heat as well. In order to make homes more energy efficient, builders have been trying to seal cracks and cut air leaks.

These efforts to tighten homes have meant that more moisture remains in the home. Unless controlled ventilation is added, moisture accumulates, and condensation occurs near the ceiling on outside walls or on outside walls of closets. These areas generally have cooler surfaces. If condensation persists on these surfaces, molds and mildews may develop. In addition, fungal growth and possible deterioration of material may occur when temperatures are at or above 50°F and the material remains wet. Such fungal growth could damage wood members in extreme circumstances.

III. BESIDES THE UDC REQUIREMENTS, WHAT MEASURES CAN HELP PREVENT MOISTURE PROBLEMS?

A. REDUCE MOISTURE PRODUCTION IN THE HOME

One way to substantially reduce the chances that condensation will occur either on inside surfaces or within walls is to keep indoor moisture levels low. The first step is to reduce the amount of moisture produced in the home. Some major sources of moisture that can be controlled are listed below.

1. *Prevent moisture from entering through basements. Many basements feel damp in the summer due to condensation of moisture from the air on cool basement surfaces. However, in some cases damp basements may be due to ground moisture entering the home through basement walls. Cracks or stains on basement walls and floors are signs of dampness entering through these surfaces.*

   You can check whether dampness is coming through walls by using a simple patch test. Tape a piece of plastic sheeting tightly against the basement wall where you suspect moisture penetration. After a couple of days pull the patch off *and look for signs of moisture on the wall side of the patch. If you detect moisture, it means moisture is coming through the wall rather than condensing on the walls.*

If you suspect a basement water problem, check the surface drainage around you home. Most basement water problems result from poor surface drainage. Make sure that the ground slopes away from the foundation. Consider installing gutters. If you have gutters, make sure they are clear of debris and functioning properly. Downspouts should direct water away from the foundation.

2. *Do not store large amounts of firewood in the basement. Even seasoned wood can contain large amounts of moisture. It also may be a source for fungus.*

3. *Other ways you can reduce moisture generation:*
   - a. *Vent clothes dryers outdoors;*
   - b. *Don't line dry clothes indoors;*
   - c. *Limit the number of houseplants;*
   - d. *Cover kettles when cooking;*
   - e. *Limit the length of showers; and*
   - f. *Do not operate a humidifier in the wintertime unless your indoor relative humidity is below 25 percent.*
   - g. *Be sure any crawlspace floors have a vapor retarder covering.*

4. *If problems persist, you should also check for any blocked chimney flues that may be preventing moisture-laden flue gasses from exhausting out of the house.*

5. *Correct any plumbing and roof leaks. If ice dams are a problem, consider more attic ventilation and adding insulation.*

B. ADD MECHANICAL VENTILATION

A second way to reduce moisture levels is to add mechanical ventilation. As an added benefit, ventilation will reduce concentrations of other possible air contaminants such as combustion by-products from heating, cooking and smoking.

A widely recommended ventilation rate for homes is one half air change per hour. In a 1,200-square-foot house with 8-foot high ceilings, there are about 9,600 cubic feet of air. To meet the ventilation standard, half of that amount or 4,800 cubic feet of air must be exchanged every hour. This roughly equals 100 cubic feet per minute (cfm) of air exchange. Even in a tight house some of this air exchange occurs naturally.

However, in a house that is experiencing severe moisture problems, it can be assumed you are getting less than one half air change per hour. A balanced ventilation system should be used to make up the remaining necessary air exchange. A balanced system is one that not only exhausts stale air but provides a source of fresh replacement air.

Currently the UDC only mandates that40% of exhaust ventilation be made up through another mean . Without proper replacement air the home could have what is known as negative air pressure.

Negative pressure could cause exhaust gases from your furnace, which should be going up your chimney or out a vent, to be sucked into the living space.

Additional ventilation is needed only during the heating season. When you provide controlled ventilation for your home, the heat lost is relatively small. For a 1,200-square-foot home, the cost of this lost energy and the electricity to run the fan would amount to about a dollar a day assuming you heat with the most expensive heat source, electric baseboard. This cost should be much less if you heat with gas or other fuels. Also, some ventilation systems can reclaim a portion of the heat (up to 80%) from the exhaust air. This could help reduce energy costs.

C. STOP MOISTURE AT THE INSIDE WALL SURFACE (IN ADDITION TO THE REQUIRED MOISTURE VAPOR RETARDER)

In addition to reducing moisture levels of the interior air, carefully seal all openings in the inside surface of all exterior walls to prevent moist air penetration. This includes joints around window and door casings, baseboards, electrical outlets and switches and any other penetrations.

Vapor Retarders Not on Warm Side

Occasionally it occurs that a wall will have two materials/layers that may act as vapor retarders. It is important in this situation that the better vapor retarder (lower perm rating) be placed closer to the warm side. Also, extreme care should be taken to make the interior vapor retarder continuous with good joint and penetration sealing. This will help avoid condensation of moisture in the wall.

In some other dwelling designs, double walls are constructed with insulation in both walls. Often this is to avoid making electrical box and other penetrations in the vapor retarder. A single vapor retarder is placed between the two walls. This conflicts with the requirements that vapor retarders be placed on the warm side of all insulation. However it may be acceptable depending on the distribution of the insulation between the two walls. If there is enough insulation on the exterior side of the vapor retarder, the air temperature in the insulation at the interior face of the vapor retarder may still be warm enough to prevent condensation.

A DEW POINT CALCULATION estimates expected temperatures throughout the thickness of the wall. Interior temperature, exterior temperature, and wall component R-values must be known. Additionally, a "design" interior air relative humidity must be assumed. Since typical wintertime reported indoor humidities range from 40 percent to 60 percent, the department will accept 50 percent as an average indoor relative humidity (RH) design value for such a calculation.

In order to do such a calculation, a person must have access to a psychrometric chart or table to determine dew points throughout the wall section given specific design temperatures, RH, and wall component R-values.

Example: Fictional Wall
R = 10, uniformly distributed across thickness of 4 inches
RH = 50% (interior)
Temp = 70° interior
-10° exterior

This would result in condensation if interior air was lowered in temperature or exposed to a surface temperature of approximately 50°. In this wall, the 50° dew point occurs at 1 inch from the interior surface. Therefore, a recessed vapor retarder must be to the inside of this 1-inch limit.

Detailed calculations shall be submitted for each specific project where a designer wishes to recess a vapor retarder into the wall cavity.

<u>Basement Floors</u>

***Question**: Is a vapor retarder required under concrete slabs?*
Answer**: Yes. The vapor retarder is required to be provided under slab-on-grade as well as basement floors.* ***Unheated *garages are exempted.*

<u>Box Sills</u>

***Question**: Is a vapor retarder required over insulation in the box sill?*
***Answer**: This section requires that a vapor retarder be provided wherever thermal insulation is installed. The department has conceded that a vapor retarder would not be effective in the box sill areas because of the numerous joints involved. A good alternative in this area would be rigid foam board or foamed-in-place insulation.*

<u>Paint as a Vapor Retarder</u>

Advances in paint chemistry have made certain paints available to contractors which, when appliid at conventional spread rates, provide a vapor retarder with a perm of 1 or lower.

This department has reviewed vapor retarder paints for application meeting the intent of s. Comm 22.22; however,does not recommend them. The evaluation method used to determine the acceptability of the paint is based on the paint's:

1. *Perm rating based on ASTM test E-96.*

2. *Scrubability as based on ASTM test D-2486.*

3. *Evaluation of manufacturer's recommendation for the paint's use.*

4. *Labeling of all paint containers.*

All test results submitted shall be from recognized independent testing agencies. The department feels that the above assures that specifically reviewed manufacturer's products will perform and not break down when applied as instructed by the manufacturer.

Two coats of vapor retarder paints are required to take into account variances in field application. Also any texturing must be applied after the vapor retarder paint.

In order to assure building officials and owners that a vapor retarder paint has in fact been installed and the intent of s. Comm 22.22 met, a certificate of compliance (see following sample certificate) may be filled out and submitted to the building official with a copy to the owner. In addition to the certificate, the contractor should provide the inspection agency with the labels from the paint cans that were used by the applicator.

The following is the recommended procedure to be followed by building inspection agencies to assure compliance with the vapor retarder requirement and yet to allow limited use of vapor retarder paint. Procedure to be followed:

1. *At the time of plan submittal, the builder should state or have shown on the plans what type of vapor retarder is to be used in the dwelling. Either manufacturer's data or a Wisconsin Materials Evaluation number shall be presented to show compliance by the chosen paint.*

2. *At the time the plan is reviewed, the inspector should provide a blank Certificate of Application if one will be locally required.*

3. *At the time the rough energy inspection is made, the inspector will be able to determine where the standard vapor retarder was applied in the dwelling.*

4. *At the final inspection, the contractor should supply to the building inspector the completed certificate as well as the labels from the paint cans.*

5. *The inspector may then destroy the labels and the Certificate of Application can be filed with the building file.*

Relative Humidity

In winter, the ideal relative humidity range for comfort is 30 percent - 45 percent. A lower humidity may cause excessive skin evaporation which in turn will cause an undesired cooling effect. For the sake of protecting the structure from damage due to excessive moisture, an ideal relative humidity range of less than 45 percent is recommended. Therefore, to provide comfort *and still protect the building, a relative humidity range of 30 percent - 45 percent is recommended.*

In summer, the ideal comfort range is 30 percent - 50 percent. Higher humidity won't allow adequate skin evaporation and the resulting desired cooling effect.

Ventilation

The code requirements of these sections for venting areas are based on effective venting area. Louvers and screening greatly decrease the effective venting of attic vents. Usually the effective venting area of a vent is indicated on it. Otherwise the following is a guide:

Obstruction in Ventilator (Louvers and Screens)	*To Determine Total Free Area of Ventilator Multiply Gross Area by:*
1/4 inch mesh hardware cloth	*1*
1/8 inch mesh screen	*0.8*
No. 16 mesh insect screen (with or without plain metal louvers)	*0.5*
Wood louvers and 1/4 inch mesh hardware cloth	*0.5*
Wood louvers and 1/8 inch mesh screen	*0.44*
Wood louvers and No. 16 mesh insect screen	*0.33*

Regarding turbine vents, the effective area is equal to the bottom opening area.

Regarding power vents, manufacturer's requirements should be followed. Otherwise an installed mechanical ventilation capacity of 0.25 cfm per square foot of attic floor area is acceptable. Additionally, adequate air intakes must be provided. Control of the fan must be provided by a humidistat or combination humidistat/thermostat. A humidistat setting of 90 percent is acceptable.

VAPOR RETARDER PAINT
CERTIFICATE OF APPLICATION

THIS CERTIFIES THAT A VAPOR RETARDER PAINT HAVING A PERM RATING BELOW 1.0 WAS APPLIED TO THE FOLLOWING STRUCTURE:

____

____

PAINT MANUFACTURER: ____

COMMERCE MATERIAL APPROVAL NO. (If Applicable)

SUPPLIER: ____

GALLONS USED: ______________________ LABELS SUBMITTED: ☐ YES ☐NO

CEILINGS - TOTAL SQUARE FEET COVERED: ____________________________

WALLS - TOTAL SQUARE FEET COVERED: ______________________________

NUMBER OF GALLONS USED ON: 1st COAT ____________ 2nd COAT ____________

APPLICATION MADE BY NAME: ____________________________________

ADDRESS: ____

SIGNATURE: ____

Comm 22.23 Walls.

(1) GENERAL. The combined thermal transmittance value (U_o) of the gross area of exterior walls shall not exceed the value given in Table 22.21. Equation 1 in s. Comm 22.31 (1) shall be used to determine acceptable combinations to meet this requirement.

(2) METAL STUD FRAMING. When metal stud framing is used, the value of U_w used in Equation 1 in s. Comm 22.31 (1) shall be recalculated using a series-parallel heat flow path procedure to correct for parallel path thermal bridging. The U_w for purposes of Equation 1 in s. Comm 22.31 (1), of metal stud walls shall be determined as follows:

$$U_w = \frac{1}{R_1 + \left(R_{ins} \times F_c\right)}$$

where:

R_1 = the total thermal resistance of the elements, in series along the path comprising the wall

assembly of heat transfer, excluding the cavity insulation and the metal stud.

R_{ins} = the R-value of the cavity insulation.

F_c = the correction factor listed in Table 22.23.

TABLE 22.23

F_c VALUES FOR WALL SECTIONS WITH METAL STUDS PARALLEL PATH CORRECTION FACTORS

SIZE OF MEMBER	SPACING OF FRAMING INCHES	CAVITY INSULATION R-VALUE	CORRECTION FACTOR
2 X 4	16 o.c.	R - 11	0.50
		R - 13	0.46
		R - 15	0.43
2 X 4	24 o.c.	R - 11	0.60
		R - 13	0.55
		R - 15	0.52
2 X 6	16 o.c.	R - 19	0.37
		R - 21	0.35
2 X 6	24 o.c.	R - 19	0.45
		R - 21	0.43
2 X 8	16 o.c.	R - 25	0.31
2 X 8	24 o.c.	R - 25	0.38

Comm 22.24 Roof and ceiling.

The combined thermal transmittance value (U_o) of the gross area of the roof or ceiling assembly shall not exceed the value given in Table 22.21. Equation 2 in s. Comm 22.31 (1) shall be used to determine acceptable combinations to meet this requirement. Skylight shafts, 12 inches in depth or greater, shall be provided with cavity insulation of R-13 and continuous insulation over framing of R-5, or have an equivalent assembly U-value.

Comm 22.25 Floors over unheated spaces.

The combined thermal transmittance value U_o of the gross area of floors that are over unheated spaces and of floors over outdoor air, such as overhangs, shall not exceed the values given in Table 22.21. Equation 3 in s. Comm 22.31 (1) shall be used to determine acceptable combinations to meet this requirement.

Comm 22.26 Slab-on-grade floors.

(1) Where the perimeter edge of a slab-on-grade floor is above grade or less than 12 inches below the finished grade, the thermal resistance of the insulation around the perimeter of the floor shall not be less than the value given in Table 22.21.

(2) Insulation shall be placed on the outside of the foundation or on the inside of a foundation wall. The insulation shall extend downward from the top of the slab for a minimum of 48-inches or downward to at least the bottom of the slab and then horizontally to the interior or exterior for a minimum total distance of 48-inches.

(3) Horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 10 inches thick. The top edge of insulation installed between the exterior wall and the edge of the interior slab may be cut at a 45 degree angle away from the exterior wall.

Comm 22.27 Crawl space walls.

(1) If the crawl space does not meet the requirements of s. Comm 22.25 and does not have ventilation openings which communicate directly with outside air, then the exterior walls of the crawl space shall have a thermal transmittance value not exceeding the value given in Table 22.21.

(2) (a) The vertical wall insulation shall extend from the top of the wall to at least the inside ground surface.

(b) Where the vertical wall insulation stops less than 12 inches below the outside finish ground level, crawl space wall insulation shall extend horizontally and vertically downward a minimum total distance of 24 inches linearly from the outside finish ground level.

Comm 22.28 Basement walls.

(1) Except as provided in subs. (3) and (4), the exterior walls of basements below uninsulated floors shall have a transmittance value not exceeding the value given in Table 22.21.

(2) (a) Except as provided in par. (b), the insulation shall extend to the level of the basement floor.

(b) Changes in the exterior insulation area and basement wall minimum thermal transmittance may be included as part of a tradeoff allowed under the method of design by system analysis or other approved compliance method.

(c) If interior insulation is used for code compliance, it shall extend the full height of the wall from basement floor to the underside of the joists above unless tradeoffs are justified by supporting calculations that consider lateral heat conduction in the wall.

(3) Where the total gross basement wall area is less than 50 percent below grade, the entire wall area, including the below-grade portion, is included as part of the gross area of exterior walls.

(4) For the purpose of determining compliance with dwelling envelope performance requirements, non-opaque areas, including windows and doors, of all basement walls shall be included in the gross area of exterior walls.

Comm 22.29 Masonry veneer.

When insulation is placed on the exterior of a foundation supporting a masonry veneer exterior, the horizontal foundation surface supporting the veneer is not required to be insulated to satisfy the foundation insulation requirement.

Comm 22.30 Air leakage.

(1) GENERAL. The requirements of this section apply to those dwelling components that separate interior dwelling conditioned space from the outdoor ambient conditions, or unconditioned spaces such as crawl spaces, and exempted portions of the dwelling from interior spaces that are heated or mechanically cooled. The requirements are not applicable to the separation of interior conditioned spaces from each other.

(2) WINDOW AND DOOR ASSEMBLIES. (a) *General.* Except as specified in par. (b), window and door assemblies installed in the building envelope shall comply with the following maximum infiltration rates, determined in accordance with ASTM E 283:

1. Windows and sliding doors shall have a maximum infiltration rate of 0.3 cfm per square foot of window area.

2. Swinging doors shall have a maximum infiltration rate of 0.5 cfm per square foot of area of the door assembly.

(b) *Exception.* Site-constructed doors and windows shall be sealed with gasketing or weatherstripping or shall be covered with a storm door or storm window.

(3) JOINT AND PENETRATION SEALING. (a) Exterior joints, seams or penetrations in the dwelling envelope, that are sources of air leakage, shall be sealed with durable caulking materials, closed with gasketing systems, taped, or covered with moisture vapor permeable house wrap. Exterior joints to be treated include all of the following:

1. Openings, cracks and joints between wall cavities and window or door frames.

2. Between separate wall assemblies or their sill-plates and foundations.

3. Between walls, roof, ceilings or attic, ceiling seals, and between separate wall panel assemblies.

4. Penetrations of utility services through walls, floor and roof assemblies, and penetrations through the wall cavity of top and bottom plates.

(b) Sealing shall be provided around tubs and showers, at the attic and crawl space panels, at recessed lights and around all plumbing and electrical penetrations, where these openings are located in the dwelling envelope between conditioned space or between the conditioned space and the outside.

Air Infiltration Barrier

The UDC does not define or limit the types of materials to be used as an infiltration barrier. It does require them to:

1. *Be installed on the exterior side of the envelope insulation.*

2. *Form a continuous surface over the walls of the building from the bearing points of the roof to the top of the foundation.*

3. *Seal all seams, joints, tears, and punctures.*

Additionally, the department feels such infiltration barrier construction:

1. *Be water vapor permeable to prevent moisture problems within the wall. The perm rating must be significantly higher than the interior vapor retarder.*

2. *Restrict infiltration to an appreciable extent.*

A specific Department of Commerce materials approval, per s. COMM 20.18, is not required for such materials due to the lack of clear code definition. However, the department has indicated that certain infiltration barrier constructions are acceptable.

These include:

- *Spun bond polyolefin sheets, with taped joints. (Ex: Tyvek by Dupont.)*

- *Micro-perforated polyethylene (Valeron) film sheets, with taped joints. (Ex: Air Stop by Diversi-Foam Products.)*

- *Tongue and groove extruded polystyrene, with taped joints.*

- *Other building panel sheets such as foam sheathing or plywood sheathing with taped joints, regardless if the panels have butt or tongue and groove edges*

Comm 22.31 Calculations.
The following equations shall be used as specified in this chapter:

(1) EQUATION 1.

$$U_0 = \frac{(U_w A_w) + (U_g A_g) + (U_d A_d)}{A_0}$$

where:

U_o = the overall thermal transmittance of the gross exterior wall area.
A_o = the gross area of the exterior walls.
U_w = the overall thermal transmittance of the various paths of heat transfer through the opaque exterior wall area.
A_w = area of exterior walls that are opaque.
U_g = the thermal transmittance of the windows.
A_g = the area of all windows within the gross wall area.
U_d = the thermal transmittance of the door area.
A_d = door area.

(a) When more than one type of wall, window or door is used, the *U* and *A* terms for those items shall be expanded into sub-elements as:

$$(U_{w1} \; A_{w1}) + (U_{w2} \; A_{w2}) + (U_{w3} \; A_{w3}) \text{ (etc.)}$$

(b) Unless exact areas are calculated, the gross exterior wall area with framing 24 inches on center shall be assumed to be at least 22% framing area, and the gross exterior wall area with framing 16-inches on center shall be assumed to be at least 25% framing area.

(2) EQUATION 2.

$$U_0 = \frac{(U_R A_R) + (U_S A_S)}{A_0}$$

where:

U_o = the overall thermal transmittance of the roof and ceiling gross area.
A_0 = the gross area of the roof and ceiling assembly.
U_R = the thermal transmittance of all elements of the opaque roof and ceiling area.
A_R = the gross area of the opaque roof and ceiling assembly.
U_S = the thermal transmittance of the area of all skylight elements in the roof and ceiling assembly.
A_S = the area, including the frame, of all skylights in the roof and ceiling assembly.

(a) When more than one type of roof or ceiling, skylight or door is used, the U and A terms for those items shall be expanded into sub-elements as:

$$(U_{R\ 1}\ A_{R\ 1}) + (U_{R\ 2}\ A_{R\ 2}) + \text{(etc.)}$$

(b) Access doors, hatches, plenums, or other areas in a roof and ceiling assembly shall be included as a sub-element of the roof and ceiling assembly.

(c) Unless exact areas are calculated, wood frame ceilings shall be assumed to be 7% framing area for joists 24-inches on center and 10% framing area for joists 16-inches on center.

(3) EQUATION 3.

$$U_0 = \frac{\left(U_{f1} \times A_{f1}\right) + \left(U_{f2} \times A_{f2}\right) + \left(U_{fn} \times A_{fn}\right)}{A_0}$$

where:

U_o = the overall thermal transmittance of the floor assembly.
A_o = the gross area of the floor assembly.
U_{fn} = the thermal transmittance of the various heat transfer paths through the floor.
A_{fn} = the area associated with the various paths of heat transfer.

(a) Unless exact areas are calculated, wood frame floors shall be assumed to be 7% framing area for joists 24-inches on center and 10% framing area for joists 16-inches on center.

(b) Access doors or hatches in a floor assembly shall be calculated as a separate element of the floor assembly using equation 3.

(4) ACCURACY OF CALCULATIONS. The thermal transmittance (U_o) values and dwelling dimensions used in heat gain or loss calculations shall have a minimum decimal accuracy of 3 places rounded to 2, except that the U_o values used for calculating ceiling transmission shall have a minimum decimal accuracy of 4 places rounded to 3.

(5) VALUES. Unless otherwise specified in this chapter, the thermal transmittance and resistance values used in heat gain and loss calculations shall be determined by one of the following methods:

(a) The values shall be those given in the ASHRAE Handbook of Fundamentals as adopted under s. Comm 20.24 (8).

Note: See the appendix under "Typical Thermal Properties of Building Materials" for the ASHRAE values.

(b) 1. Testing to a nationally recognized test standard by an independent third party that is submitted for department review and approval under s. Comm 20.18.

2. The testing shall verify the claimed thermal resistance for the specific application of the product or assembly.

3. For foam plastic insulation that uses a blowing agent other than air, the independent third-party tests shall use samples that have been aged for the equivalent of 5 years or until the R-value has stabilized.

Note: See Appendix for a table of R-values reprinted from the ASHRAE Handbook of Fundamentals.

Comm 22.32 Recessed lighting fixtures.

When installed in the dwelling envelope, recessed lighting fixtures shall meet any one of the following requirements:

(1) The fixture shall be inherently or thermally protected type IC and installed inside an air-tight assembly maintaining any clearances required by the listing.

(2) The fixture shall be inherently or thermally protected type IC, manufactured with no penetrations between the inside of the recessed fixture and ceiling cavity, and sealed or gasketed to prevent air leakage into the unconditioned space.

(3) The fixture shall be inherently or thermally protected type IC, and labeled as being tested in accordance with ASTM E 283 at a pressure difference of 75 pascals or 1.57 lb/ft^2 with no more than 2.0 cfm air movement from the conditioned space to the ceiling cavity.

Subchapter VII — Design by Systems Analysis and Design of Dwellings Utilizing Renewable Energy Sources

Comm 22.33 General.

The requirements of Subchapter V, "Heating and Air Conditioning Equipment and Systems" and the requirements of Subchapter VI, "Dwelling Envelope Design" establish design criteria for energy-consuming and enclosure elements of the dwelling. As an alternative, an energy use analysis may be used to show equivalent compliance. The analysis shall comply with this subchapter or shall be approved by the department.

Note: The department recognizes the use of tradeoffs between higher efficiency furnaces and lower insulation levels. See appendix for an example of the UDC Energy Worksheet. Copies of the worksheet may be obtained from the Department of Commerce, Safety & Buildings Division, P.O. Box 2509, Madison, WI 53701. Other forms or software may be used when approved by the department. WIScheck software may be used to show compliance and is available from the Safety & Buildings page on the Department of Commerce Website www.commerce.state.wi.us.

Comm 22.335 Definitions. In this subchapter:

(1) "Glazing area" means the total area of the glazed fenestration measured using the rough opening and including sash, curbing or other framing elements that enclose conditioned space. For doors where the daylight opening area is less than 50 percent of the door area, the glazing area is the daylight opening area. For all other doors, the glazing area is the rough opening area for the door including the door and the frame.

(2) "Proposed design" means a description of the proposed building design used to estimate annual energy costs for determining compliance based on total building performance.

(3) "Standard design" means a dwelling whose enclosure elements and energy-consuming systems are designed in accordance with subchs. V and VI.

(4) "Substantially leak free" means the condition under which the entire air distribution system, including the air handler cabinet, is capable of maintaining a 0.1-inch water gage, or 25 Pa, internal pressure at 5 percent or less of the air handler's rated airflow when the return grilles and supply registers are sealed off, using a test method approved by the department.

Note: The department will accept tests conducted using the SMACNA HVAC Air Duct Leakage Test Manual, or other, similar test methods.

Comm 22.34 Energy analysis.

(1) Newly constructed one- and 2-family dwellings designed in accordance with this subchapter comply with Subchapters V and VI if the calculated annual energy consumption is not greater than a similar dwelling, designed as a standard design, whose energy-consuming systems and enclosure elements are designed in accordance with Subchapters V and VI**.**

Note: In this subchapter, "Standard design" means a dwelling whose enclosure elements and energy-consuming systems are designed in accordance with Subchapters V and VI.

(2) For a proposed alternate dwelling design to be considered similar to a standard design, it shall utilize the same energy sources for the same functions and have equal conditioned floor area and the same ratio of dwelling envelope area to floor area, exterior design conditions, climate data, and usage operational schedule.

Comm 22.35 Input values.

(1) GENERAL. The input values in this section shall be used in calculating annual energy performance. The requirements of this section specifically indicate which variables shall remain constant between the standard dwelling and proposed dwelling calculations. The standard dwelling shall be a base-version of the design that directly complies with the provisions of this chapter. The proposed dwelling may utilize a design that is demonstrated, through calculations satisfactory to the department, to have equal or lower annual energy use than the standard design.

(2) INPUT VALUES FOR GLAZING AND SHADING SYSTEMS. (a) *Orientation of standard design*. The orientation of the standard design shall have equal area on the north, northeast, south, southwest, east, southeast, west, and northwest exposures.

(b) *Shading calculations for proposed design.* Results from shading calculations on a proposed design may not be used for groups of buildings, unless those results constitute the worst possible building orientation in terms of annual energy use, considering all eight of the orientations under par. (a) for a group of otherwise identical proposed designs.

(c) *Exterior shading for standard design.* 1. Glazed areas in the standard design may not be provided with extra exterior shading such as roof overhangs.

2. The energy performance impacts of added exterior shading for glazing areas may be accounted for in the proposed design for a specific dwelling, provided that the actual installation of such systems is approved by the department.

(d) *Fenestration system solar heat gain coefficient, standard design.* 1. The fenestration system solar heat gain coefficient, or SHGC, inclusive of framed sash and glazing area, of the glazing systems in the standard design shall be 0.68 during periods of mechanical heating and cooling operation.

2. a. The fenestration system SHGC values shall be multiplied by interior shading values of 0.70 for summer and 0.90 for winter to arrive at an overall SHGC for the glazing system.

b. Where the SHGC characteristics of the proposed fenestration products are not known, the default SHGC values given in Table 22.35-3 shall be used for the proposed design.

(e) *Interior shading for standard and proposed designs.* 1. a. Except as specified in subd. 2., the same schedule of interior shading values, expressed as the fraction of the solar heat gain admitted by the fenestration system that is also admitted by the interior shading, shall be assumed for the standard and proposed designs.

b. The values used for interior shading shall be 0.70 in summer, and 0.90 in winter.

2. South-facing solar gain apertures on passive heating proposed designs analyzed using interior shading values for interior shading specific to those shading measures may be specified in the proposed design, with values above used in the standard design.

(f) *Passive solar designs.* Passive solar designs shall provide documentation acceptable to the department, that fixed external or other acceptable shading is provided to limit excessive summer cooling energy gains to the dwelling interior.

(3) INPUT VALUES FOR HEAT STORAGE AND THERMAL MASS. (a) Internal mass shall be 8 pounds per square foot.

(b) Structural mass shall be 3.5 pounds per square foot.

(c) Passive solar designs shall utilize at least 45 Btu/°F of additional thermal mass, per square foot of added glass area, when south-facing glass exceeds 33 percent of the total glass area in walls.

(4) INPUT VALUES FOR DWELLING ENVELOPE. (a) Surface area and volume.

1. Floors, walls and ceilings of the standard and proposed designs shall have equal areas.

2. The foundations and floor types for both the standard and the proposed designs shall be equal.

3. a. The exterior door area of the standard design shall have an equal exterior door area to that of the proposed design with a U-factor of 0.2 Btu/h. ft.^{2} ^{o}F.

b. The U_d of the standard design shall be selected to permit calculated U_o wall compliance of the standard design.

4. Building volume of both the standard and proposed design shall be equal.

(b) HVAC controls. Heating and cooling thermostats shall be set to the default settings in Table 22.35-1 for the standard and proposed designs. The input values, specific to heating and cooling controls, shall be used in calculating annual energy performance.

TABLE 22.35-1
INPUT VALUES FOR HVAC CONTROLS

Parameter	Value
Heating	68°F (20°C)
Cooling	78°F (26°C)
Set back or set up	5°F (2.8°C)
Set back or set up duration	6 hours per day
Number of set back or set up periods per unit	1
Maximum number of zones per unit	2
Number of thermostats per zone	1

(c) Internal heat gains. The input value of 3,000 Btu/hr per dwelling unit, specific to internal heat gains, shall be used in calculating annual energy performance.

(d) Domestic hot water. The following input values, specific to domestic hot water, shall be used in calculating annual energy performance:

1. The temperature set point is 120°F.

2. Daily hot water consumption in gallons = (30 x a)+ (10 x b) where a = number of dwelling units in standard and proposed designs and b = number of bedrooms in each dwelling.

(5) SITE WEATHER DATA CONSTANTS. Weather data from the typical meteorological year or its equivalent from the National Oceanic and Atmospheric Administration or an approved equivalent for the closest available location shall be used.

(6) DISTRIBUTION SYSTEM LOSS FACTORS. (a) The heating and cooling systems efficiency shall be proportionally adjusted for those portions of the ductwork located outside or inside the conditioned space using the following equations:

1. Adjusted Efficiency = Equipment Efficiency x Distribution Loss Factor

2. Total Adjusted System Efficiency = (Adjusted Efficiency x percent of ducts outside) + (Adjusted Efficiency x percent of ducts inside).

3. Distribution loss factors shall be determined using Table 22.35-2.

TABLE 22.35-2
DISTRIBUTION LOSS FACTORS

Mode	Duct Location *	
	Outside	Inside
Heating	0.75	1.00
Cooling	0.80	1.00

* Ducts located in a heated or cooled space are considered to be in an inside location.

(b) Impacts from an improved distribution loss factor, or DLF, shall be accounted for in the proposed design only if the entire air distribution system is specified on the construction documents to be substantially leak free, and is tested after installation to ensure that the installation is substantially leak free.

(c) Where test results show that the entire distribution system is substantially leak free, the seasonal DLF shall be calculated separately for heating and cooling modes using engineering methods or programs capable of considering the net seasonal cooling energy heat gain impacts and the net seasonal heating energy heat loss impacts that result from the portion of the thermal air distribution system that is located outside the conditioned space.

(d) Once these heating and cooling season distribution system energy impacts are known, the heating and cooling mode DLF for the proposed design shall be calculated using the following two equations:

1. Total Seasonal Energy = Seasonal Building Energy + Distribution System Energy Impacts

2. DLF = Seasonal Building Energy ÷ Total Seasonal Energy

(e) Once the DLF for the heating and cooling seasons are known, the total adjusted system efficiency is calculated using the following equations and conditions:

1. Adjusted System Efficiency = (Equipment Efficiency x DLF x Percent of Duct Outside) + (Equipment Efficiency x DLF x Percent of Duct Inside)

2. a. This equation shall be used to develop adjusted system efficiency for each heating and cooling system included in the standard design.

b. Where a single system provides both heating and cooling, efficiencies shall be calculated separately for heating and cooling modes.

TABLE 22.35-3
SOLAR HEAT GAIN COEFFICIENTS FOR GLAZING

PRODUCT	SINGLE GLAZED				DOUBLE GLAZED			
	Clear	Bronze	Green	Gray	Clear + Clear	Bronze + Clear	Green + Clear	Gray + Clear
Metal Frame Operable Fixed	 0.75 0.78	 0.64 0.67	 0.62 0.65	 0.61 0.64	 0.66 0.68	 0.55 0.57	 0.53 0.55	 0.52 0.54
Nonmetal Frame Operable Fixed	0.63 0.75	0.54 0.64	0.53 0.62	0.52 0.61	0.55 0.66	0.46 0.54	0.45 0.53	0.44 0.52

(7) AIR INFILTRATION. (a) For the purpose of calculation, air changes per hour for the standard design is 0.50.

(b) If the proposed design takes credit for a reduced air change per hour level, documentation of the measures providing the reduction or the results of a post-construction blower-door test conducted in accordance with ASTM E 779 shall be provided to the department. In no case shall the air exchange per hour value be less than 0.20.

Comm 22.36 Design. The standard design and the proposed alternative design shall be designed on a common basis as specified in this section:

(1) The comparison shall be expressed in Btu input per square foot of gross floor area per year or other time unit, at the dwelling site.

(2) If the proposed alternative design results in an increase in consumption of one energy source and a decrease in another energy source, even though similar sources are used for similar purposes, the difference in each energy source shall be converted to equivalent energy units for purposes of comparing the total energy used.

(3) The different energy sources shall be compared on the basis of energy use at the dwelling site where 1 kWh = 3,413 Btu.

Comm 22.37 Analysis procedure. The dwelling heating and cooling load calculation procedures shall be detailed to permit the evaluation factors specified in s. Comm 22.38 to provide a comparison of energy consumption between the alternative design and the standard design.

Comm 22.38 Calculation procedure.

The calculation procedure shall cover all of the following items that are expected to have a significant impact on the comparison of the energy consumption between the alternate design and the proposed design:

(1) Environmental design requirements as specified in Subchapter IV.

(2) Coincident hourly climatic data for temperatures, solar radiation, wind and humidity of typical days in the year representing seasonal variation.

(3) Dwelling orientation, size, shape, mass and volume.

(4) Air, moisture and heat transfer characteristics.

(5) Operational characteristics of controls for inside air temperature, humidity, ventilation, lighting, and the control mode for occupied and unoccupied hours.

(6) Mechanical equipment design capacity load profile.

(7) Dwelling loads of internal heat generation, lighting, equipment, and the number of occupants during occupied and unoccupied periods.

Comm 22.39 Use of approved calculation tool.

The same calculation tool or method shall be used to estimate the energy usage for space heating and cooling of the standard design and the proposed design. The calculation tool or method and the documentation shall be approved by the department.

Comm 22.40 Documentation.

Proposed alternative designs submitted as requests for exception to the standard design criteria shall be accompanied by an energy analysis comparison report. The report shall provide technical detail on the two dwellings, system designs, and data used in and resulting from the comparative analysis verifying that both analysis designs meet the criteria of this chapter.

SAMPLE

HOME PERFORMANCE RATING

REM/Rate v8.46 - Wisconsin

SAMPLE

Uniform Dwelling Code Compliance Option Reports

For more information contact:

Home Performance Rating
211 South Paterson Street
Madison, WI 53703
1-800-677-8423
Fax 608-249-0339

Date:
Owner's
Property
Address:
Builder's
Weather
Builder's
Element
Roofs/Ce
Above-G
Slab Floc
Basemer
OVERAL
This DES
Code. (C
This REN
conserva
Building
Roof/Cei
Roof
Above-G
Wall
Joist
Joist
Windo
Windo
Windo
Windo
Windo
Door
Slab Flo
Expos
Baseme
Wall
Wall

SAMPLE

Wisconsin Uniform Dwelling Code Compliance By Annual Energy Analysis

Date:	January 04, 1999	Rating No.:	
Owner's Name:	UDC4	Rating Org.:	
Property		Phone No.:	
Address:	Milwaukee, WI	Rater's Name:	
		Rater's No.:	
Builder's Name:			
Weather Site:	Milwaukee, WI	Rating Type:	Based On Plans
Builder's File:	UDC42.BLG	Rating Date:	

Annual Energy Consumption (MMBtu)

	UDC	As Designed
Heating:	97.6	89.1
Cooling:	4.6	4.8
Total:	102.2	93.9 *

This DESIGN meets the annual energy consumption requirements of the Wisconsin Uniform Dwelling Code. (COMM Chapter 22, Subchapter VII.) Surpasses UDC requirements by 8%

This REM/Rate report is a Department of Commerce approved method of showing compliance with the energy conservation standards of Chapter COMM 22 of the Uniform Dwelling Code.

* Design consumption is based on the following heating/cooling system:
  Heating: Fuel-fired air distribution, 60.0 kBtuh, 78.0 AFUE.
  Cooling: Air conditioner, 24.0 kBtuh, 10.0 SEER.

In accordance with the Uniform Dwelling Code, building inputs such as setpoints, infiltration rates, and window shading may have been changed prior to calculating annual energy consumption.

SAMPLE

SAMPLE

EQUIPMENT SIZING SUMMARY

Date:	January 04, 1999	Rating No.:	
Owner's Name:	UDC4	Rating Org.:	
Property		Phone No.:	
Address:	Milwaukee, WI	Rater's Name:	
		Rater's No.:	
Builder's Name:			
Weather Site:	UDC Design Zone 4, WI	Rating Type:	Based On Plans
Builder's File:	UDC42.BLG	Rating Date:	

	udc42
HEATING	
Calculated Peak Load (kBtu/hr)	48.2
Oversize Factor (%)	115.0
HEATING EQUIPMENT CAPACITY (kBtu/hr)	
Calculated	55.4
Specified	60.0
COOLING	
Calculated Peak Load (kBtu/hr)	21.0
Sensible	17.0
Latent	4.0
Oversize Factor (%)	100.0
COOLING EQUIPMENT CAPACITY (kBtu/hr)	
Calculated	21.0
Specified	24.0
SENSIBLE HEAT FRACTION (SHF)	
Calculated	0.81
Specified	0.70

Heating equipment capacity calculated using Wisconsin Uniform Dwelling Code ambient design temperature. (COMM Chapter 22, Subchapter IV, Table 22.07-2.) Indoor set points used: Heating 68.0 Cooling 78.00

REM/Rate - Residential Energy Analysis and Rating Software v8.46 Wisconsin

SAMPLE

ENERGY COST AND FEATURE REPORT

Date:	January 04, 1999	Rating No.:	
Owner's Name:	UDC4	Rating Org.:	
Property		Phone No.:	
Address:	Milwaukee, WI	Rater's Name:	
		Rater's No.:	
Builder's Name:			
Weather Site:	Milwaukee, WI	Rating Type:	Based On Plans
Builder's File:	UDC42.BLG	Rating Date:	

ANNUAL ENERGY COSTS		udc42
Heating	$	512
Cooling	$	106
Water Heating	$	128
Lights & Appliances	$	461
Service Charges	$	114
Total	$	1321
Average Monthly	$	110

ENERGY FEATURES

Ceiling w/Attic	R38 Attc (2x4 24oc) U=0.026
Vaulted Ceiling	None
Above Grade Walls	R19 (2x6 16oc) R5 U=0.043
Foundation Walls	R-10.0
Doors	R-1.7 w/storm
Windows	D W Op (LoE/Ar HC) U=0.390
Window Shading	H: Some C: Some
Frame Floors	None
Slab Floors	UninsulatedR-0
Infiltration	H: 7.50 C: 7.50 ACH50
Infilt. Measure	Blower door test
Interior Mass	None
Heating System	Fuel-fired air distribution
Heating Efficiency	78.0 AFUE
Cooling System	Air conditioner
Cooling Efficiency	10.0 SEER
Water Heating System	Conventional, Gas
Water Heating Efficiency	0.58 EF
Ducts	Uninsulated
Active Solar	None
Sunspace	No

Notes: Where feature level varies in home, the dominant value is shown.

REM/Rate - Residential Energy Analysis and Rating Software v8.46 Wisconsin

Permit #
Checked by/Date

WIScheck COMPLIANCE REPORT
Wisconsin Uniform Dwelling Code
WIScheck Software Version 1.0

TITLE: UDC Chapter 22 Compliance Example

COUNTY: Dane
HEATING TYPE: Non-Electric
DATE: 1-4-1999
DATE OF PLANS: 1/4/99
PROJECT INFORMATION:
1500 ft2 house in Dane County

Sample Report

COMPANY INFORMATION:
Builder's Business Name

NOTES:
Windows are certified by NFRC. See attached manufacturer's specifications.

UDC COMPLIANCE: PASSES

Required UA = 373
Your Home = 349
6.5% Better Than Code

	Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing/Door U-Value	UA
CEILINGS	1500	19.0	19.0		39
WALLS: Wood Frame, 16" O.C.	1316	13.0	5.0		84
WALLS: Wood Frame, 16" O.C.	151	13.0	5.0		10
BSMT: Conc. 8.0' ht/7.0' bg/8.0' insul	1468	0.0	5.0		132
GLAZING: Windows or Doors, Above Grade	75			0.350	26
GLAZING: Windows or Doors, Above Grade	75			0.370	28
GLAZING: Windows, Basement/Foundation	20			0.870	17
DOORS	38			0.350	13
HVAC EQUIPMENT: Furnace, 90.0 AFUE					

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the requirements of the Wisconsin Uniform Dwelling Code.

Builder/Designer________________________________ Date______________

WIScheck Report Sample

TITLE: UDC Chapter 22 Compliance Example

Heating Equipment Sizing Summary

General Information

Outdoor Design Temperature:	-15	deg
Conditioned Floor Area:	1500	ft2
Average Ceiling Height:	8.0	ft
Infiltration Rate:	0.50	Normalized ACH
Equipment Oversizing Factor:	15.0	%

Loads Summary

Conductive Losses:	29725	Btu/hr
Infiltration Losses:	9180	Btu/hr
Oversizing Factor Losses:	5836	Btu/hr
Total Building Heating Load:	44741	Btu/hr

WIScheck Report Sample

Comm 22.41 Renewable energy source analysis.

(1) A proposed dwelling utilizing solar, geothermal, wind or other renewable energy sources for all or part of its energy sources shall meet the requirements of s. Comm 22.33, except such renewable energy may be excluded from the total annual energy consumption allowed for the proposed dwelling by this subchapter.

(2) To qualify for the exclusion in sub (1), the renewable energy must be derived from a specific collection, storage, and distribution system. The solar energy passing through windows shall also be considered as qualifying if such windows are provided with one of the following:

(a) Operable insulation shutters or other devices which, when drawn or closed, cause the window area to reduce maximum outward heat flows to those in accordance with s. Comm 22.31 (2), and the windows are shaded from direct solar radiation during periods when mechanical cooling is requested.

(b) The glass is double or triple pane insulated glass with a low-emittant coating on one or both surfaces of the glass, or insulated glass with a low-emittant plastic film suspended in the air space, and the glass areas are shaded from direct solar radiation during periods when mechanical cooling is requested.

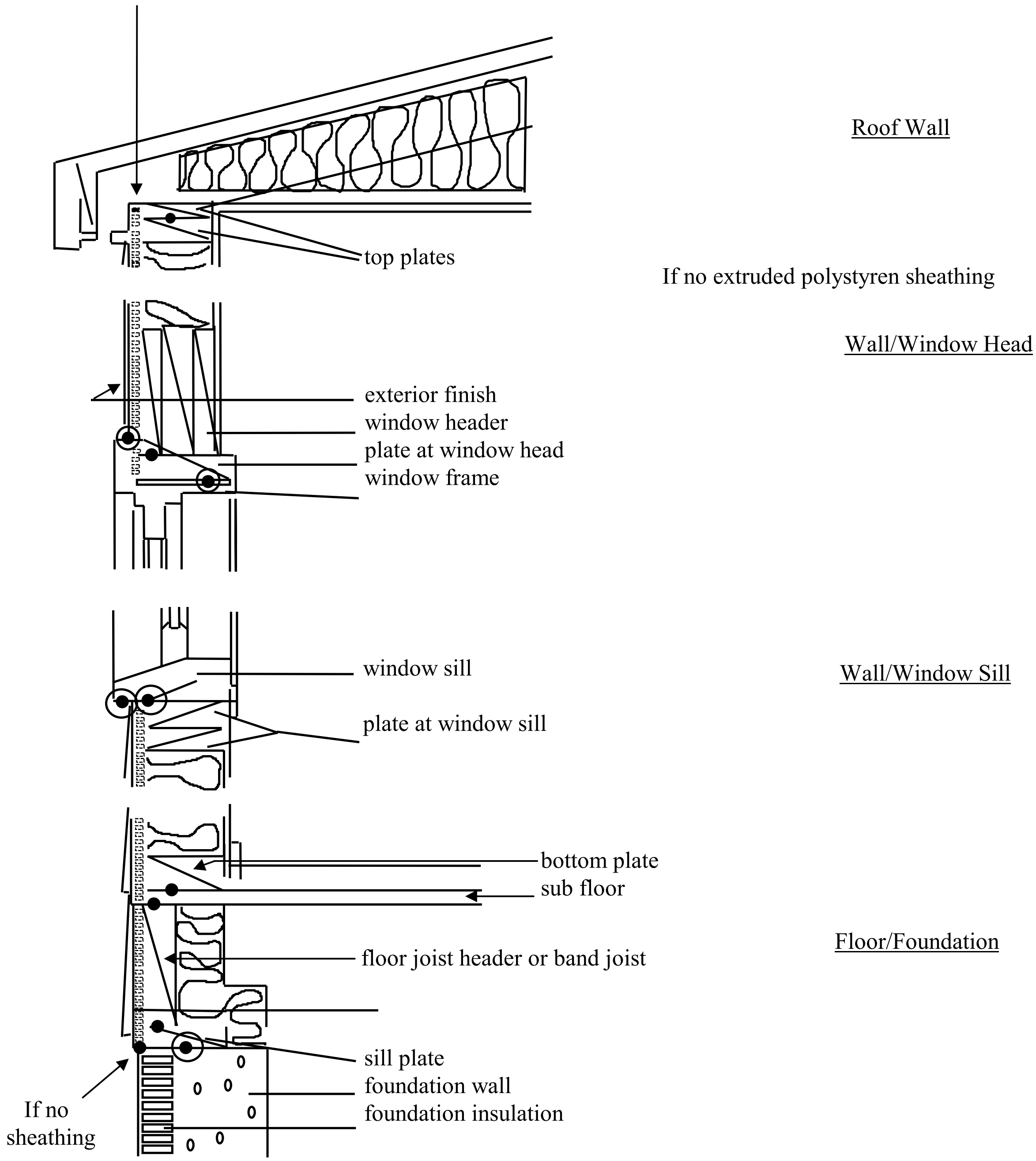
(3) Other criteria covered in s. Comm 22.23 to 22.39 shall apply to the proposed alternative designs utilizing renewable sources of energy.

Comm 22.42 Documentation.

(1) Proposed alternative designs submitted as requests for an exception to the standard design criteria, shall be accompanied by an energy analysis, as specified in s. Comm 22.40. The report shall provide technical detail on the alternative dwelling, system designs, and the data employed in and resulting from the comparative analysis to verify that both the analysis and the designs meet the criteria of this code.

(2) The energy derived from renewable sources and the reduction in conventional energy requirements derived from nocturnal cooling shall be separately identified from the overall dwelling energy use. Supporting documentation on the basis of the performance estimates for the renewable energy sources and nocturnal cooling means specified in this subchapter shall be submitted to the department.

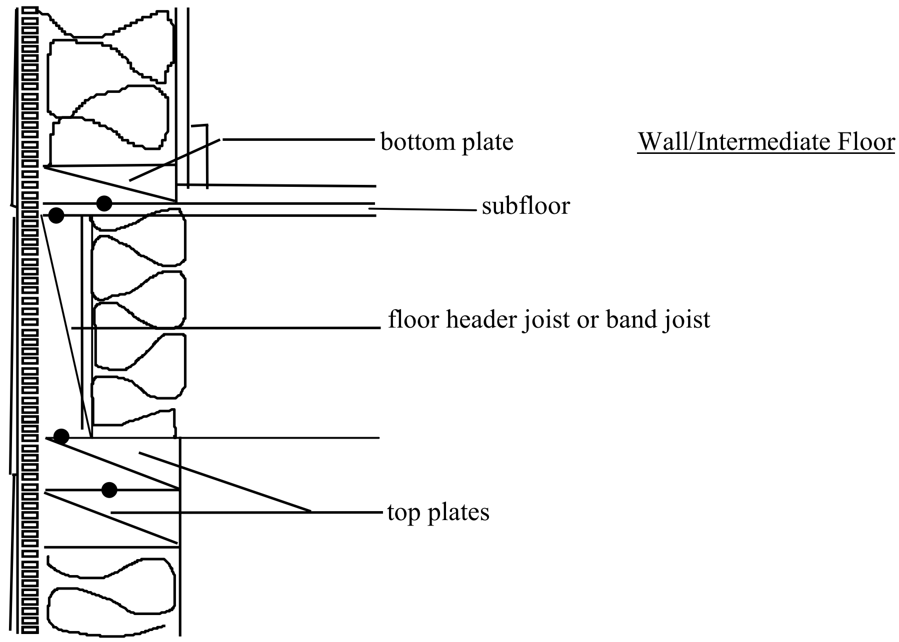
s\sb\commentaries\ch22

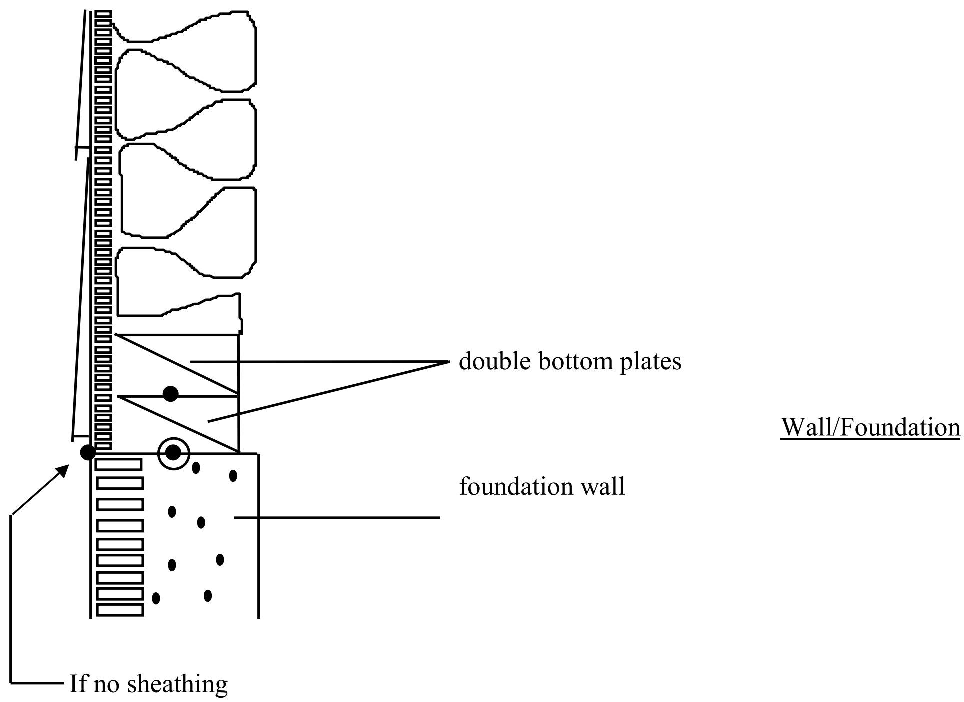


Caulk, Gasket or Seal:

Mandatory; also (not shown):

- All utility penetrations
- Between door thresholds and subfloor
- Between joist header and foundation
- Exterior joints at cantilevered floors, bay windows and soffitts (floor to wall, wall to roof, but not wall to wall joints)
- Separate wall panels in panelized construction


bottom plate
Wall/Intermediate Floor
subfloor
floor header joist or band joist
top plates


double bottom plates
Wall/Foundation
foundation wall
If no sheathing